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EVALUATION OF LIQUID DETERGENTS AND METHODS USED FOR AIRFIELD RUBBER REMOVAL

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14. ABSTRACT

Four separate detergents were tested to determine their effectiveness in airfield rubber removal to restore friction. Each detergent is applied to the pavement surface in controlled 50' x 30' patches. There were three patches placed for each detergent with increasing levels of mechanical effort and agitation duration ranging from 2 to 4 hours. Upon completion of agitation, a water trailer and spray bar was employed to sufficiently rinse the airfield surface and neutralize the detergent agents. Friction measurements were conducted prior to and after cleaning with a GripTester device towed at a constant velocity of 40 mph.

15. SUBJECT TERMS

rubber removal, friction evaluation, Avion 50, DC 101, JBS Citrus, Hurrisafe, NASA Grease Smear Method, airfield maintenance

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1. EXECUTIVE SUMMARY

This research effort was conducted at Duke Airfield in Crestview, Florida to evaluate rubber removal detergent methodologies and determine the combined effectiveness of each detergent to improve overall runway friction. Various detergents were used to dissolve and remove embedded rubber particles from within the micro- and macro-texture of airfield runways with respect to environmental impacts and airfield downtime.

A series of experiments was performed and four separate detergents used at three different contact durations and varying agitation efforts along a portion of the runway with heaviest rubber deposits. Each detergent was applied to the surface area of 50 ft x 30 ft which bi-sected the runway centerline. One side of the centerline in each detergent area received twice the mechanical agitation effort as the other. Loosened rubber deposits were washed from the runway surface using a pressurized water delivery system to force all remaining debris to the runway edge.

Pre- and post-friction measurements were obtained using a continuous friction measuring equipment (CFME) within all tested areas and later compared to determine overall effectiveness of the combined materials and methods.

While it was concluded that Avion 50 detergent out-performed the other three detergents with regards to cleaning efficiency and final visual appearance after rinsing the test area, the average friction improvement after testing was inconclusive. The airfield had very little rubber build-up prior to cleaning and was categorized as very light to light over the entire test section. The impact of cleaning a runway surface with light build-up was negligible as related to friction loss or gain, therefore the only conclusive evidence found at the conclusion of testing was purely visual.

2. INTRODUCTION

2.1. Background

The runway is the lifeline to a successful airfield operation. A rigorous and timely maintenance program is imperative to the sustainment of safe and controlled aircraft activity which prevents inevitable deterioration caused by regular traffic.

Over a specific time period, frequent air traffic can significantly degrade the friction functionality of a runway surface. The micro- and macro-texture of runways are drastically reduced with the accumulation of rubber which can be detrimental in wet conditions causing reduced friction [1]. It has been found that a single landing can transfer as much as 1.4 lbs of rubber from each aircraft tires into the micro- and macro-texture of a runway. Over time, the rubber build up saturates all surface void space and begins to eliminate available surface roughness, thus reducing the necessary friction coefficient for aircraft control upon takeoff and landing [2].

Friction coefficient values (μ) average 0.8–1.0 for new construction, post-usage values can fall to 0.3–0.4 within weeks or months (depending on traffic frequency and type). Values in this range severely limit aircraft control at higher speeds during wet weather operations, thus presenting safety hazards for incoming and outgoing aircraft. Consequently, the need arose for investigation into viable methods of rubber removal from airfield surfaces.

To reverse and maintain this build-up of rubber deposits, research has been conducted to identify efficient methods of removal using detergent agents for rubber dissolution combined with mechanical scrubbing to loosen the compacted particles and restore a proper frictional coefficient to the runway surface. The detergents soften the deposited rubber and turn it into a form that can be brushed or scraped off [3].

2.2. Objective

The objective of this research was to develop an expedient method for removal of rubber deposits from airfield runways using a detergent based system which could be C-130 transportable. Four separate detergents and two different scrubbing durations were compared to ultimately determine the most efficient and effective combination of materials and methods. A CFME was used to evaluate the friction differential between pre- and post-cleansing surface conditions.

2.3. Report Organization

This report details the recommended equipment, methods, and detergents used for periodic airfield rubber removal. Section 3 discusses the detergent application and rubber removal equipment needed in this research as well as detergent properties and potential environmental concerns. Section 4 displays the site preparation and layout in a detailed schematic. Section 5 discusses the micro- and macro-friction coefficient test methods that were used for this research. Section 6 explains the test preparation and cleaning protocol with all the steps needed to ensure proper rubber removal. Section 7 examines the pre-cleaning measurements and the evaluation of these results. Section 8 shows the proper technique of detergent application and rubber removal. The runway and layout data sheets are also provided in this section for each detergent used in this research. Section 9 examines the post-cleaning friction measurements and the evaluation. Section 10 includes the conclusion of this research with each detergent examined as well as a friction analysis

3. RUBBER REMOVAL EQUIPMENT AND MATERIALS

To achieve sufficient rubber removal in the shortest time period possible, the procurement and use of proper equipment is required. Likewise, the detergent chosen to loosen and liquefy the rubber mass bears great significance to the final friction improvement of the airfield pavement surface. The following is an outline of the equipment and detergent used during this test regime.

3.1. Mechanical Agitation and Scrubbing Equipment

Each detergent test area was mechanically agitated and scrubbed for varying time periods as outlined in the original test plan. A diesel powered Toolcat® with a hydraulic kick broom attachment was used to forcefully remove the loosened and dissolved rubber material from the impacted voids.

3.1.1. Hydraulically-Operated Toolcat®

The Toolcat® (manufactured by Bobcat®) is chosen for testing because of its versatility and size. The Toolcat® and all necessary ancillary items can be loaded on one C-130 aircraft. The Toolcat® is easily maneuverable in and around confined areas and has a top speed of 18 mph. A front-mounted kick broom attachment (Figure 1) and rear-mounted spray system can operate simultaneously or independently, depending on the operational needs during the rubber removal process. It also offers an enclosed cab which shields the operator from detergent misting and foreign debris.

Figure 1. Hydraulic Broom Attachment Agitating Detergents

3.1.2. Broom Attachment

The broom attachment (Figure 2) has a 4:1 combination of steel and poly bristles. Poly bristles are needed to increase the movement of water while the steel bristles provide the deep scrubbing action and remove the rubber material. This combination of steel and poly bristles has been used commercially to obtain optimal results with the detergent rubber removal operation. Early work at the Air Force Research Laboratory (AFRL) demonstrated that this combination is more effective than using the broom attachment loaded with only steel or only poly bristles.

The following list details the broom equipment and applicable dimensions:

- Model: 84-inch Angle Broom (Bobcat®)
- Hydraulic Drive: 15–28 gal/min hydraulic direct drive
- Broom Angling Function: Hydraulic
- Operating Weight: 944 lbs (428.2 kg)—standard 50 wafer bristle configuration; 1060 lbs (480.8 kg) - recommended 90 wafer bristle configuration
- Bristle Diameter: 10.0 in (25.4 cm) inner diameter, 32.0 in (81.3 cm) outer diameter
- Overall Dimension: 61.0 in (154.9 cm) long; 96.8 in (245.9 cm) wide

Figure 2. Hydraulic Rotary Broom Attachment

3.1.3. Detergent Spray Bar System

The detergent application system has two main components: a pumping mechanism and a spray bar attachment. During the experiment, two different pumping mechanisms were used: a gasoline-powered pump and a hydraulically-driven system powered by the Toolcat® vehicle. The hydraulically-driven system malfunctioned and was replaced throughout testing by the gasoline-powered pump. Each system delivered the chosen detergent from an on-board holding tank to a 21-ft collapsible spray bar attachment as shown below in Figure 3.

The spray bar consisted of 13 nozzles spaced evenly across with maximum operating pressures of 50 psi each. The flow rate exiting the nozzles remained consistent and applied coverage is determined by the forward speed of the Toolcat®. Because coverage requirements differed by detergent, the forward speed of the Toolcat® was adjusted to compensate. Detergent application will be discussed in greater detail later in this report.

Figure 3. Toolcat® Applying Detergents with 21-ft Spray Bar

3.1.4. Water Rinse Down Trailer

To effectively remove applied detergents and loosened rubber from the airfield surface after cleaning, large quantities of water were required. Water sources are typically located long distances from the runway and water transportation to the cleaning site can be timely and cumbersome without proper equipment. Since all equipment included in this kit must be C-130 transportable, overall size is a constraint. To overcome the challenge of mass water delivery to the site, a transforming rinse-down trailer was developed to fit onto a 463L pallet for air transport.

Once on site, the trailer is transformed into its operational state as shown in Figure 4. A 2,000 gallon nylon bladder is placed into the expanded trailer bed which can be filled to capacity within minutes using a local fire hydrant. The bladder valve is connected to a series of flexible pipes that lead to a gasoline-power water pump attached directly to the trailer infrastructure. The outflow of the pump is piped to a rigid metal spray bar assembly mounted on the port trailer side. The spray bar assembly consists of 16 independent nozzles oriented at approximately 30 degrees forward from vertical to produce a “sweeping effect” wave motion which efficiently flushes loosened rubber and all remaining site debris from airfield surface. Each nozzle operates at approximately 35 psi with a nominal total flow rate of 250 gal/min across the bar.

The rinse-down trailer system produces enough volume and pressure to sufficiently remove the loose rubber particles and dissolved slurry, while neutralizing the highly basic nature of the detergent compounds and eliminating environmental impacts.

Figure 4. Water Rinse Trailer—Travel Mode to Full Assembly

3.1.5. Findley-Irvine GripTester

The friction data is collected and compiled using a Findley-Irvine GripTester CFME device provided by the Air Force Civil Engineering Support Agency (AFCESA) as shown in Figure 5. The device can be towed behind any ½-ton (or larger) vehicle with adequate storage capacity for a metered water delivery system and equipped with a receiver hitch. The GripTester unit records real-time friction coefficients of the airfield pavement surface.

Figure 5. Findley-Irvine GripTester Device

This CFME device is a lightweight, three-wheeled trailer which weighs 183 lb (83 kg) and is operated using a single, smooth tread tire that is mechanically forced to slip at 14.5 percent of the relative trailer forward speed. The differential slip is controlled by a calibrated, chain-driven transmission directly linking the skid tire and the main wheel axle.

3.1.5.1. GripTester Operation

The device is towed at a constant velocity of 40 mph (nominal speed) within the test area to determine both pre- and post- cleaning macro-texture coefficients. Data recording is started 500 ft from the threshold end and terminated 500 ft from the opposite end to allow for adequate acceleration and deceleration distances [3]. Water is delivered to the device via a storage tank mounted within the tow vehicle at a constant flow rate which produces a 1-mm (0.04-in) thick film of water just before the American Society of Testing and Materials (ASTM) measuring tire to simulate wet weather operations. Water cannot completely be squeezed out between the runway and tire, resulting in partial contact between the two objects [4].

Sensors are fitted about the wheel axle which measures differential wheel rotation speed and provides continuous data to the on-board computer and instrumentation package. The acquired data is normally streamed to a connected laptop computer located within the tow vehicle. The software shows friction values as spot readings, averages between events, averages over each third of the runway, or as an average over the entire runway length. A graph showing friction readings versus distance travelled may also be obtained [4].

3.1.5.2. GripTester Calibration

An integral part of friction measurement using the GripTester is a proper calibration prior to use. The unit used for this experiment was properly calibrated prior to use.

3.1.5.3. Tire Pressure

Ensuring correct pressure in all GripTester tires was vital to the success and accuracy of the surface friction measurements. Prior to use, all tires on the device were inspected and they were filled to the appropriate pressure of the 20 psi required by ASTM.

3.1.5.4. Tire Condition and Expiration Date

It is important to use a skid tire that is still within its service life and without signs of damage or uneven wearing. The measuring tire should be visually inspected for excessive wear and still within its expiration date. For this test series however, a brand new skid tire was installed onto the GripTester trailer prior to test commencement.

3.1.5.5. Chain Tension

The chain tension was checked and adjusted to manufacturer's specifications before testing. This ensured that the proper slip ratio was maintained between the measuring tire and the drive tires.

3.1.5.6. Sensor Gap

The differential velocity between the ASTM measuring tire and the drive tires is measured by the GripTester device and used to derive available surface friction. To monitor and record the differential velocities, the trailer is equipped with a sensor between the rotating axle of the skid tire and a fixed point on the trailer. The gap between these two points is required to be maintained at 0.7-mm ± 0.1-mm prior to and during testing. This gap distance is critical in obtaining accurate test data. Prior to use during this test series, the sensor gap was verified and adjusted as required to within tolerance.

3.1.5.7. Electronic Data Collector Setup
The GripTester device is equipped with an internal calibration and data transmission computer system. Immediately prior to use, the computer variables must be properly set and the calibration parameters defined. These system checks were performed on site moments before the test series began.

3.1.5.8. Wet Weather Simulation
During friction measurement operations, the GripTester device emits a controlled flow of water at a specified flow rate directly in front of the ASTM skid tire. This function of the device simulates wet weather conditions. The flow rate is calculated as a function of the tow vehicle forward velocity and the required water depth in front of the skid tire. The flow rate for this series of tests was adjusted to produce a water thickness of one millimeter. Prior to test commencement, the water delivery system is calibrated to ensure an accurate volume per unit time using a stopwatch and a five gallon bucket which had been pre-defined with a required fill line. The water volume used for test wetting is recorded for future use and compared to the theoretical volume for a given speed and distance travelled.

3.2. Liquid Detergents

The liquid detergents used during testing were selected based upon criteria including total water consumption, direct cost, corrosive properties, environmental impacts, and the requirement for post-cleaning water neutralization. Four different rubber removal detergents were comparatively evaluated and the final determination of effectiveness and efficiency was based upon field performance evaluations and differential friction measurements between pre- and post-analysis. Each detergent product was tested using three different contact times and two different mechanical effort durations. The MSDS documentation for each detergent tested can be located in Appendix A.

3.2.1. Avion 50
Avion 50 is a product of Chemtek Incorporated (Yanceyville, NC, USA) and is a highly corrosive liquid detergent. Personal protective equipment (PPE) should be worn when handling this product. It was the highest cost agent tested and had the highest pH level (13) of all specimens used. Avion 50 was the control group for comparative evaluation of all other agent performances. Regardless of its caustic nature, this detergent out-performed all others tested with regard to cleaning efficiency by volume and final visual appearance of the rinsed test area.

3.2.2. DC-101
DC-101 is a product of Saric Solutions (Fuquay-Varina, NC, USA) and was procured from CleanEDGE, LLP, located in Baltimore, Maryland, USA. This detergent has a pH of 8.0 which is considerably lower than the control detergent and yields coverage of 10,000–12,000 sq ft per 55-gal drum, or 60,000 sq ft per 275-gal tote. It is non-toxic, water soluble, non-flammable, and environmentally safe. It is also fully biodegradable and has a shelf life of two years.

3.2.3. Hurrisafe
This detergent is manufactured by PCI of America (Rockville, MD, USA) and is the second most corrosive agent tested at a pH of 12.4. It was just slightly more expensive per unit gallon than the cheapest product tested. It has the best coverage area of all evaluated at 450 sq ft/gal. It required

less water per test area relative to the other detergents and it visually resulted in a very clean airfield pavement.

3.2.4. JBS Citrus

This detergent is produced by JBS Industries (Lebanon, OH, USA) and possesses a pH of 9.0. Relative to others tested, it performed poorly from a visual standpoint. Dark streaks on the airfield pavement surface were evident after the rinse procedure was complete.

The following table outlines the manufacturers recommended usage guidelines and applicable characteristics for all test detergents:

Table 1. Rubber Removal Detergent Information

Detergent	* Reaction Time (soak-agitate-rinse)	* Water Requirement (gal)	* Detergent Volume (gal)	Detergent Cost (per gal)	* Total Detergent Cost	pH
Avion50	00:30 - 03:00 - 03:00	30,000	550	$11.00	$6,050.00	13
DC-101	00:20 - 01:00 - 10:00	12,000	550	$9.00	$4,950.00	8
Hurrisafe	00:30 - 03:00 - 03:00	7,500	220	$9.00	$1,980.00	12.4
JBS Citrus	4-6 passes (light) 8-10 passes (heavy)	Until Clean	340	$8.07	$2,744.73	9

**For 100,000 square foot pavement surface*

Table 2. Detergent Application Chart

Detergent	Coverage (sq. ft. / gal)	Patch Test Volume Required	Flow Rate Required (gal/ft)	Application Speed (mph)
Avion50	180	8.3	0.08	3.1
DC-101	180	8.3	0.08	3.1
Hurrisafe	450	3.3	0.03	7.8
JBS Citrus	290	5.2	0.05	5.1

**For 100,000 square foot pavement surface*

4. OVERALL SITE LAYOUT

A series of rubber removal tests were conducted at Duke Airfield, auxiliary field to Eglin AFB during the dates of January 19–29, 2010. Duke Field is essentially a self-contained installation located in Valparaiso, FL. Test areas were restricted to the northern end of Runway 18 as shown in Figure 6. Due to active status of the test airfield, the site was delineated and marked accordingly upon arrival each night and then broken down prior to departure the following morning. The detergent test zone was established using orange cones with glow sticks attached at the corners of each of the three duration areas. These areas were separated by a distance of 50 linear feet. The markers were placed using a calibrated wheel measuring device.

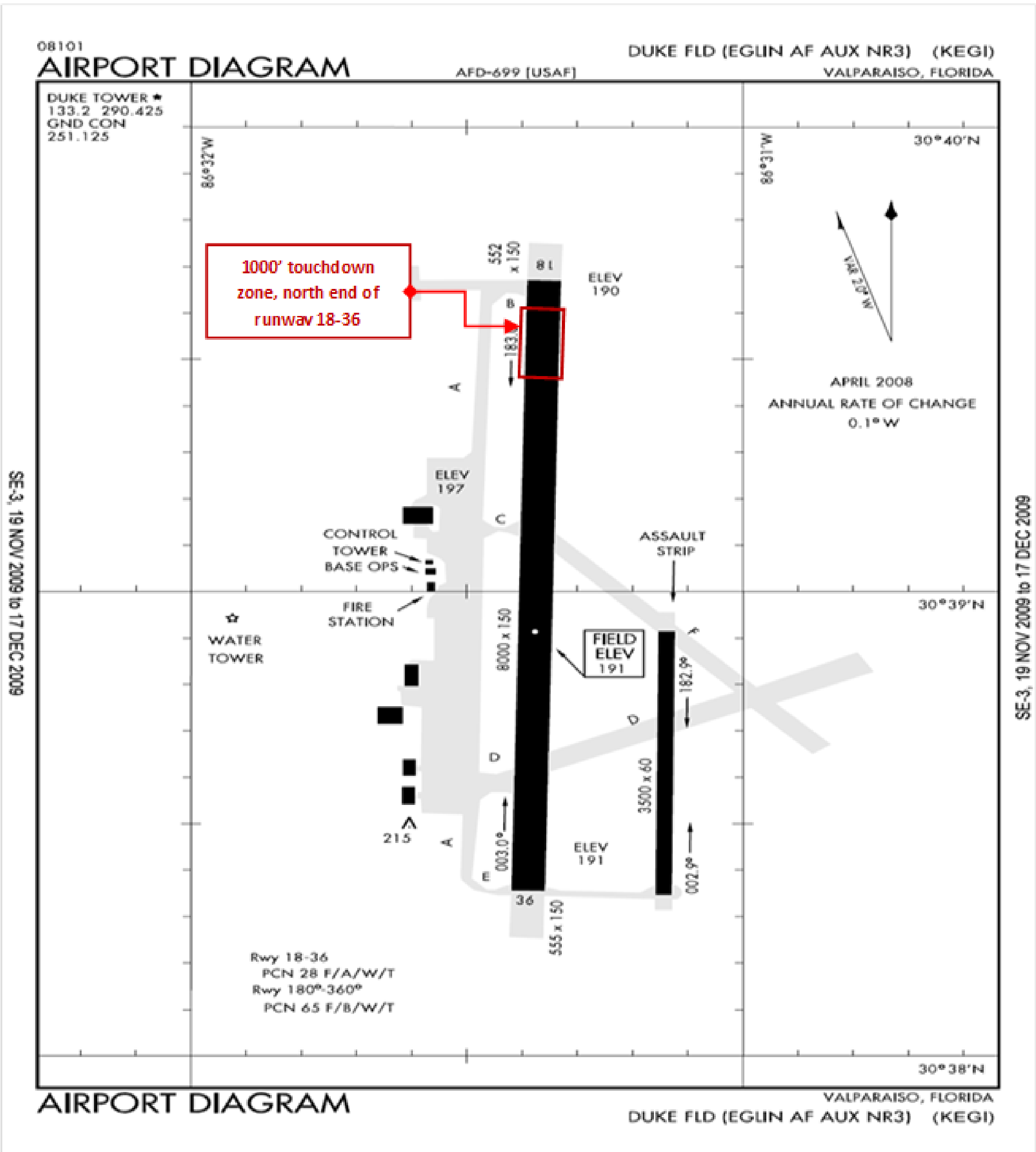


Figure 6. Duke Airfield Test Site Overview

Friction data was collected prior to detergent application in order to obtain pre-cleaning coefficient values and develop a control basis for final analysis. Detergents were then applied and allowed to soak for a set period following manufacturer's recommendations of time before mechanical scrubbing commenced to loosen the dissolved rubber and remaining particulates. The test protocol varied the scrubbing durations in order to determine potential benefits from longer sweeping/agitation cycles. Each detergent was then thoroughly rinsed using a pressurized water system to neutralize the agent and prevent possible environmental impacts. Post-cleaning friction measurements were obtained in the same method as the pre-cleaning routine. The data compiled was used in a comparative analysis to determine detergent effectiveness as related to type, concentration, contact time, and mechanical agitation duration.

4.1. Test Site Layout

The test site was divided into four distinct detergent zones; one for each detergent being tested. Within each zone there were three subzones (Figure 8) which represented different levels of mechanical scrubbing effort and detergent contact times of two, three, and four hours, respectively. Each subzone is bisected longitudinally by the existing airfield centerline striping. Test sections were segregated by 25 linear foot transition intervals between one another to provide adequate maneuverability during detergent application and to ensure ease of data analysis across the test spectrum. The site layout is shown below in Figure 7.

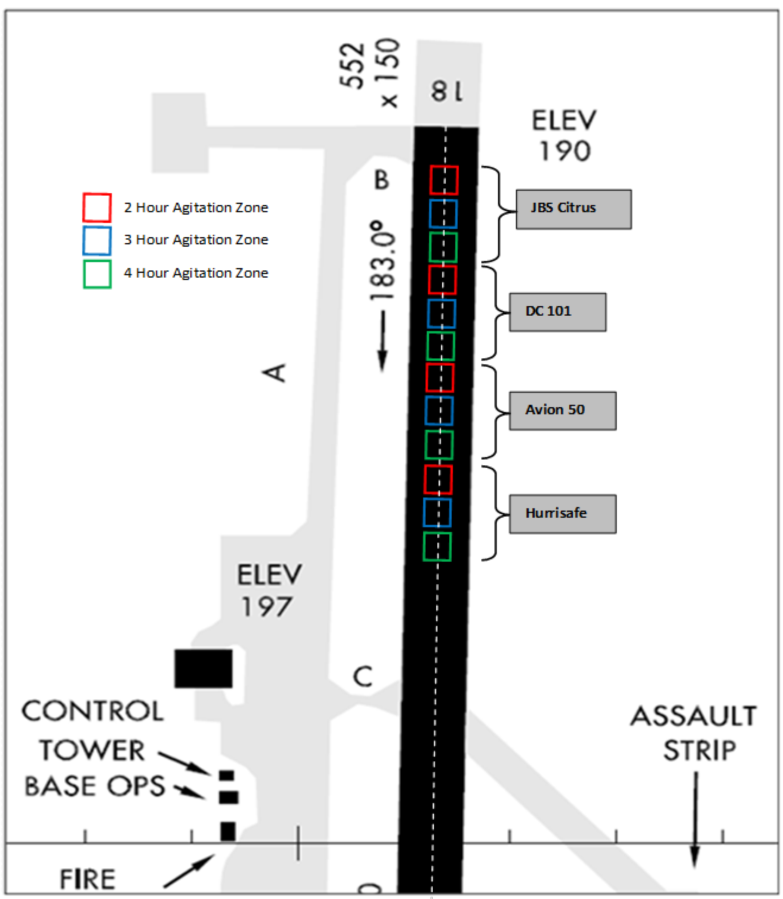


Figure 7. Overall Site Layout by Detergent Type

4.2. Mechanical Effort Layout

Twelve subzones (three per detergent type) of dimension 50-ft long × 30-ft wide were surveyed on the touchdown zone of Runway 18 in areas with no less than 75 percent coverage of rubber deposits. The bisected test areas spanned 15 ft to either side of runway centerline; one of the bisections received twice the mechanical scrubbing effort as the other. This allowed for additional comparison of frictional enhancement as directly related to agitation effort and overall duration. The subzones were clearly marked with cones or similar markers at all corners for visual reference.

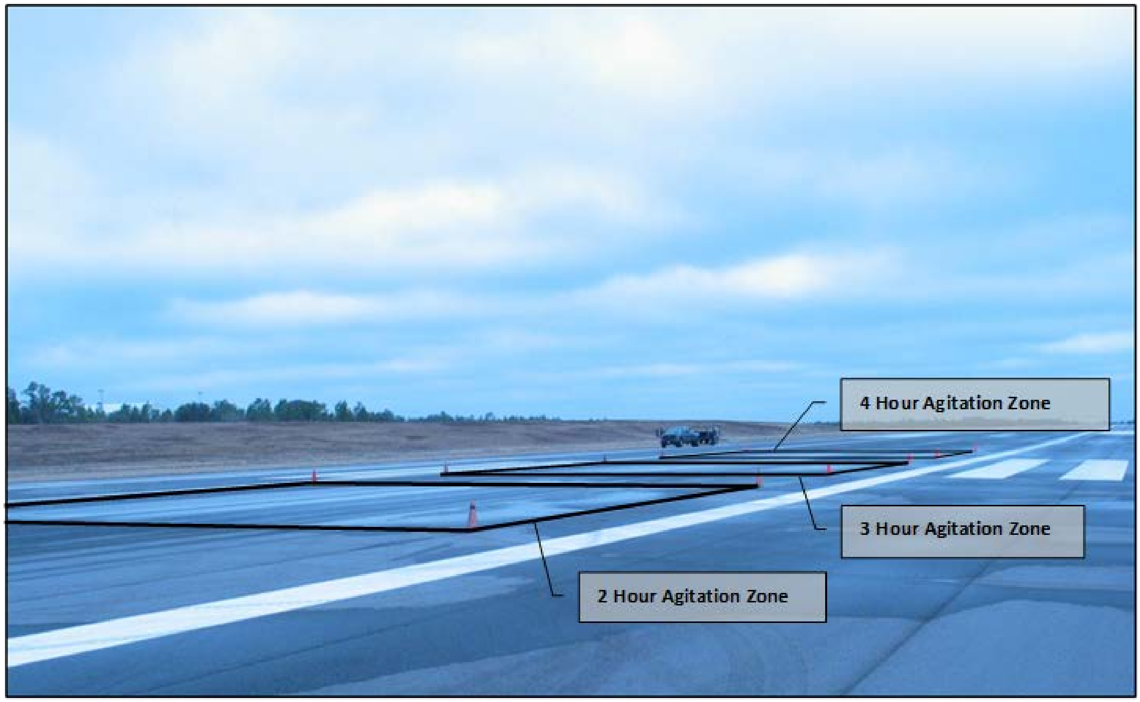


Figure 8. Typical Detergent Zone Layout by Agitation Duration

5. FRICTION EVALUATION METHODS

5.1. CFME Data Collection Method

A total of 12 passes with the CFME were performed on both sides of the runway centerline, for a total of 24 passes within the overall test site area for pre- and post-cleaning. This protocol was performed for both pre- and post-cleaning scenarios. The tow vehicle began just inside the bisected area nearest the centerline and worked outward for each pass. This represented the average friction along the width of the test area. This method then generated a total of 36 data points for each detergent zone, 12 points for each detergent duration and 6 points for each of the two mechanical agitation bisects (by detergent type).

The GripTester was used in “drive mode”; a setting which collects friction measurements by passing over the entire test area distances a specific number of times at a specific velocity. All data compiled was plotted using this software function.

In addition, ambient temperature, wind direction and velocity, and relative humidity measurements were recorded prior to testing for future reference.

5.2. NASA Grease Smear Test

Additional texture measurements were obtained from the airfield surface using the National Aeronautics and Space Administration (NASA) Grease Smear Method. This method determines the overall texture depth of the pavement surface by forcing a finite volume of grease into the macro-texture over a specified coverage area [3]. Grease smear tests were completed during both pre- and post-cleaning friction evaluations for comparison. Twelve smear tests were performed on each side of the runway within the test area at an offset distance of 7.5 ft from centerline. Testing began at a distance of 1,025 ft from primary and test locations were longitudinally spaced apart at distances of 75 ft. A total of 48 grease smear tests were performed overall. For purposes of direct comparison and determination of removal effectiveness, post- cleaning smear tests were placed in the exact location as the pre-cleaning routine.

For visual reference, Figure 9 illustrates the application process. A specialized metal template 4-in wide was placed onto the airfield surface in its pre-determined test location. A measured volume of 15 cm^3 of grease was placed via syringe onto the pavement surface within the template boundaries. The grease is smoothed across the pavement surface using a proprietary blade and nominal hand pressure to a uniform depth until all available grease has been depleted into the underlying texture voids. The smear length is then measured to the nearest quarter inch and recorded for future reference. The measured length of the smear is directly proportional to the overall texture depth within the template area; a greater texture depth yields a shorter smear length. Pre-cleaning smear test data is finally compared to post-cleaning data from the exact same location within the test area to obtain a percentage difference for analysis.

Figure 9. Grease Application within Template

6. TEST PREPARATION AND CLEANING PROTOCOL

6.1. Environmental Data Collection

The following data are necessary to perform a comprehensive analysis of detergents:

- temperature/dew point
- wind speed
- pre-test friction
- water volume used for pavement wetting
- detergent volume applied
- agitation cycle times
- quantity of rinse water used
- quantity of rinse water lost
- post-test friction

Compiled field notes and recorded data for each detergent trail were logged onto Runway Layout and Information sheets. The information from each sheet has been summarized and provided in Section 8.4; actual field notes are located in Appendix B.

6.1.1. Local Weather

Prior to beginning test procedures each day, the local weather was obtained from Duke Field Base Operations Weather Team. Whereas the detergents are subject to evaporation loss at higher ambient temperatures and drier conditions, these factors were not an issue during this test series because the majority of cleaning efforts were performed after dark from the hours of 2300 to 0600. Ambient temperatures recorded were between 40 °F and 60 °F throughout the entire removal period and all detergents were sufficiently rinsed prior to the daylight hours. Current weather data is vital to detergent performance analysis and the development of a weather relationship to full scale removal success.

6.1.2. Wind Speed/Direction

The wind speed and direction were recorded prior to testing each day. These values were obtained from Duke Field Base Operations Weather Team; specific to the KPAM location. The wind speed is important because it affects moisture levels on the pavement surface.

6.2. Slope Measurements

Runway slopes were measured prior to friction analysis and rubber removal. These measurements were taken to indentify ponding issues that could adversely affect friction. Two different slope measurements were recorded at each location; longitudinal and transverse. The longitudinal slope was measured along the runway centerline and the transverse slope was measured perpendicular to the centerline [5]. Figure 10 and Figure 11 show the slope measurement being measured in the field. The slope measurement field notes are located in Appendix A.

Figure 10. Slope Measurement

Figure 11. Slope Measurement Reading

6.3. Periodic Pavement Wetting

This particular test series was performed exclusively at night in windy and cold conditions. Despite the cooler conditions, the combination of humidity and moderate cross winds were causing rapid drying of the airfield surface. The sprayed water aided in maintaining surface moisture and allowed for proper foaming action during agitation. This is normally performed to maintain the reactive nature of the detergents and impede evaporation. The volume of water applied is minimal relative to the volume of detergent used, so dilution of the detergent base is of no concern.

Water from an available fire hydrant near the test area was utilized to fill the storage tank aboard the Toolcat® and was then transported back to the test site area. The pavement surface was then dampened as needed after initial detergent application.

6.4. Agitation Plan

One of the test plan conditions was to determine the effectiveness of increased broom agitation efforts by dividing the test areas in two by using airstrip centerline; one side received twice the mechanical effort as the other. As it was laid out, the side right of the centerline (as bearing 360°) received greater effort. This helped determine if the extra labor cost and time significance of additional agitation efforts were warranted relative to each individual detergent type.

The mechanical agitation began on the outermost sides of the test section and traversed inward toward the centerline in 3 ½ foot intervals as it moved across each 15 foot side and down the 50 foot section length. The broom was angled such that the slurry was pushed toward the centerline. Once centerline was reached, the Toolcat® followed the same path back, changing the broom angle to push outward and moved the slurry toward the edge of the runway. This back and forth cycle across the width was duplicated for each set time interval. A 15 minute time window was then allowed for further soaking and penetration of the detergent. The amount of time required for each agitation series and subsequent soak time was recorded for future analysis.

6.4.1. Rinsing Procedure

After completing the agitation cycle, the runway was fully rinsed using the transforming water trailer with spray bar and pump system. Rinsing began at the centerline of each cleaning zone and proceeded outward until all slurry and rubber debris had been cleared from the runway surface and onto the adjacent grassed area. The volume of water used for the rinse cycle was fully sufficient for complete detergent neutralization prior to entering the surrounding environment. Approximate water volume used and time required for the rinse cycle for each zone was noted.

7. PRE-CLEANING MEASUREMENT AND EVALUATION

A friction analysis was performed prior to detergent application to determine the level of existing rubber build-up and the effective friction as a result. Testing was conducted at speeds of 40 mph at a bearing of 180° (and 360°) along the longitudinal runway axis. Runs were random within the marked test areas, traversing the entire 30-ft wide test width. Testing encompassed a series of 12 runs in order to develop an accurate nominal average; six runs down (bearing 180°) and six runs back (bearing 360°). The GripTester device provided real time friction measurements every two feet along the 875-ft test parameter.

It must be noted that the airfield surface did not possess a significant amount of existing rubber build-up. The airfield has been recently re-surfaced and sufficient time had not yet passed to produce a level of rubber which neared the threshold of required cleaning.

The airfield as it existed prior to cleaning is shown in several photographs below. Figure 12 represents a view from the northern edge of the testing area facing south (18–36) and Figure 13 represents a view from the southern edge of the testing area, facing north (36–18).

Figure 12. Existing Test Site Rubber (18–36)

Figure 13. Existing Test Site Rubber (36–18)

7.1. GripTester Device (CFME) Results

The following tables outline average friction data measurements for each pre-cleaning run (40 mph) relative to individual detergent test areas and agitation zone:

Table 3. Pre-Cleaning Average Mu Values (CFME)

Chemical Zones / Agitation Duration		1x Mechanical Agitation Zone							2x Mechanical Agitation Zone						
		Run Number							Run Number						
		1	2	3	4	5	6	Average Mu (µ)	7	8	9	10	11	12	Average Mu (µ)
JBS CITRUS	2 Hr	0.46	0.64	0.59	0.54	0.47	0.50	0.53	0.48	0.37	0.52	0.34	0.47	0.32	0.42
	3 Hr	0.38	0.54	0.43	0.50	0.45	0.51	0.47	0.50	0.38	0.49	0.33	0.49	0.41	0.43
	4 Hr	0.62	0.61	0.48	0.51	0.66	0.46	0.55	0.67	0.40	0.55	0.49	0.58	0.40	0.51
DC 101	2 Hr	0.65	0.63	0.56	0.55	0.61	0.45	0.57	0.58	0.47	0.54	0.38	0.56	0.45	0.49
	3 Hr	0.52	0.59	0.47	0.48	0.48	0.36	0.48	0.53	0.41	0.53	0.44	0.49	0.45	0.48
	4 Hr	0.55	0.58	0.58	0.64	0.57	0.58	0.58	0.56	0.54	0.60	0.47	0.51	0.49	0.53
AVION 50	2 Hr	0.58	0.58	0.58	0.64	0.57	0.58	0.59	0.56	0.54	0.60	0.47	0.57	0.49	0.54
	3 Hr	0.43	0.52	0.42	0.63	0.49	0.53	0.50	0.48	0.45	0.42	0.38	0.45	0.45	0.44
	4 Hr	0.42	0.64	0.50	0.65	0.51	0.56	0.55	0.58	0.41	0.44	0.39	0.39	0.44	0.44
HURRISAFE	2 Hr	0.53	0.57	0.45	0.62	0.45	0.63	0.54	0.46	0.60	0.37	0.59	0.35	0.61	0.50
	3 Hr	0.51	0.62	0.46	0.65	0.54	0.68	0.57	0.47	0.50	0.50	0.43	0.48	0.51	0.48
	4 Hr	0.55	0.58	0.38	0.39	0.41	0.51	0.47	0.44	0.44	0.38	0.37	0.33	0.33	0.38

The average Mu values for the 2x agitation zone are higher than the average Mu values for 1x agitation zone. This is an indicator that the right hand side of the runway (as bearing 360°) had less rubber then the left side. The average Mu value for the right had side is approximately 0.53 while the left had side average Mu value is approximately 0.47. Table 4 represents the friction level classification for runway surfaces using a CFME system.

Table 4. Friction Level Classification for Runway Pavement Surfaces Using CFME with Self-Wetting System [6]

Test Device	65 km/h (40mph)			95 km/h (60mph)		
	Action Level	Planning Level	New Design/Construction	Action Level	Planning Level	New Design/Construction
GripTester Friction Tester	0.43	0.53	0.74	0.24	0.36	0.64

The pre-cleaning Mu values represent a small amount of rubber existing on the runway. Once the Mu values reach a certain level of friction, an action needs to be taken to remove the rubber and improve friction. This value of this testing is 0.43. There are only two out of the twenty four average Mu values than fall beneath this value that require an action to be taken. The planning level value where preparation needs to start to determine when rubber needs to be removed is 0.53 and fourteen of the averages fall within this zone of planning leaving eight that fall above the planning stage.

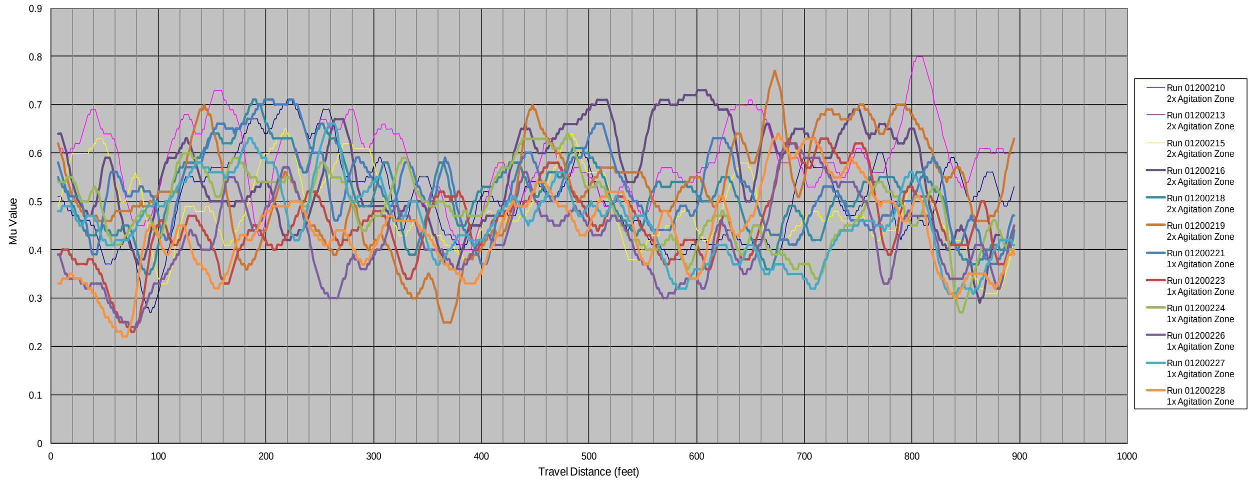


Figure 14. Pre-Cleaning Micro-Texture Data Graph (GT View Data)

7.2. NASA Grease Smear Test Results

For ease of viewing, the collective information obtained during the pre-cleaning Grease Smear Test is presented in Section 9.2 alongside the data obtained from the post-cleaning test. The existing values were directly compared to the post-cleaning test data in order to determine the difference in available friction levels and the overall effectiveness yielded by each detergent agent.

Texture depth is used to classify hydroplaning potential for aircraft on runway. Hydroplaning occurs when contact between a tire and the surface is lost due to water pressure build up in the tire-ground contact area [7]. The classification levels are shown in Table 5 along with the classification criteria of texture depth.

Table 5. Texture Depth Level Classification for using NASA Grease Smear Testing [3]

Average Texture Depth (ATD)	Hydroplaning Potential
<0.016"	Strong (1)
0.017" - 0.035"	Further Testing Required (2)
>0.036"	Low (3)

The pre-cleaning texture depths on both sides of the centerline are classified as needing further testing excluding one which has a strong potential for hydroplaning as seen inTable 6. Removing the existing rubber on the runway would increase texture depth and potentially lessen the risk of hydroplaning.

Table 6. Pre-Cleaning Texture Depth

		Right of Centerline			Left of Centerline		
FT From Primary	Vol. of grease (cc)	Grease Area Covered (sq-cm)	Texture Depth (cm)	Hydroplaning Potential	Grease Area Covered (sq-cm)	Texture Depth (cm)	Hydroplaning Potential
1025	15	632.26	0.024	2	529.03	0.028	2
1100	15	851.61	0.018	2	670.97	0.022	2
1175	15	516.13	0.029	2	593.55	0.025	2
1250	15	490.32	0.031	2	890.32	0.017	2
1325	15	670.97	0.022	2	490.32	0.031	2
1400	15	929.03	0.016	1	851.61	0.018	2
1475	15	748.39	0.020	2	451.61	0.033	2
1550	15	567.74	0.026	2	774.19	0.019	2
1625	15	677.42	0.022	2	580.64	0.026	2
1700	15	754.84	0.020	2	658.06	0.023	2
1775	15	561.29	0.027	2	774.19	0.019	2
1850	15	554.84	0.027	2	464.52	0.032	2

** bearing at 180 degrees*

7.3. Slope Measurements

The transverse and longitudinal slope was found for each side of the runway (with bearing at 180°) as shown in Figure 15. Table 7 shows the slopes measured with all having a (+) positive slope with the longitudinal measurements being almost completely horizontal.

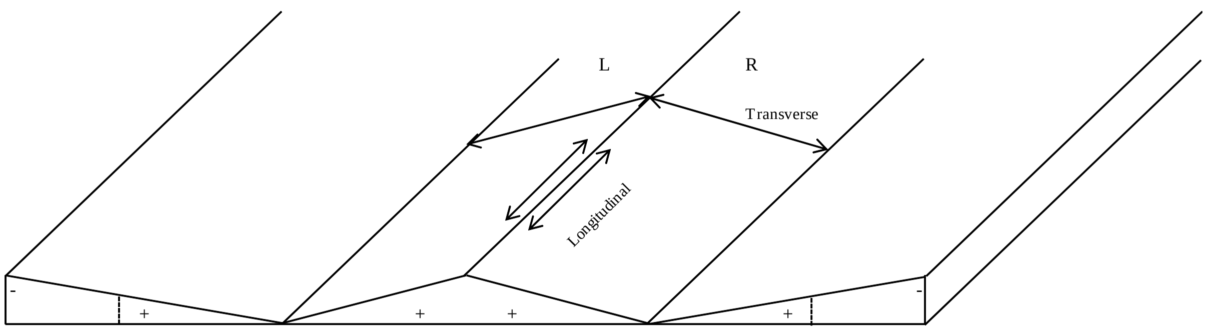


Figure 15. Runway Cross-Section for Slope Measurements

Table 7. Slope Measurement Data

FT from Primary	Longitudinal Right (%)	Right (%)	Left (%)	Longitudinal Left (%)
1025	+0.1	+0.8	+0.7	+0.2
1100	+0.4	+1.4	+0.9	+0.4
1175	+0.4	+1.1	+1.0	+0.5
1250	+0.5	+0.2	+1.4	+0.6
1325	+0.3	+0.1	+1.4	+0.3
1400	+0.2	+0.4	+1.3	+0.1
1475	+0.2	+0.7	+0.9	0.0
1550	+0.3	+1.3	+0.6	+0.2
1625	+0.2	+1.2	+0.7	+0.2
1700	+0.3	+0.8	+1.0	+0.3
1775	+0.3	+0.6	+1.1	+0.4
1850	+0.2	+0.4	+1.1	+0.2

8. DETERGENT APPLICATION AND RUBBER REMOVAL

8.1. Toolcat® Preparation

The Toolcat® was prepared for the rubber removal process at least a day ahead of the start time to make sure all is working properly. All attachments were checked for proper operation and the spray bar nozzles were inspected to ensure flow accuracy and proper detergent application onto the surface. The spray bar was folded and secured prior to travel.

8.1.1. Magnetic Bar Placement for Foreign Object Debris (FOD)

A magnetic bar was mounted via wired rope cables at the rear of the vehicle and oriented such that the magnet hung approximately one half inch above the airfield surface. Its purpose was to remove metallic FOD and broken wire broom bristles from the airfield during agitation. The magnetic bar is shown in Figure 16.

Figure 16. Magnetic Bar Orientation on Toolcat®

8.2. Rinse Trailer Preparation

The rinse trailer required initial transformation from its folded state into a fully functional water delivery system. The liner was installed and the bladder was carefully placed into the liner. Caution was used to avoid bladder damage during setup. Due to the relative location of the hydrant to the airfield test site, an initial filling of the bladder in advance was necessary to prevent time loss later. The filled trailer was towed to the site vicinity and remained there until the agitation process was complete and the rinsing procedure was ready to commence.

The trailer bladder has a capacity of 2,000 gallons and was filled via a fire hose attached directly to the available fire hydrant. The approximate time for filling was 15–20 minutes; this time did not include travel to and from the hydrant location after each depletion.

8.2.1. Water Pump and Spray Bar Adjustment

The trailer was equipped with a water pump and spray bar configuration as seen in Figure 17. The pump is modified with a remote starting device which allowed the truck operator to start and stop the water flow as needed from the truck cab. The pump is checked for fuel and the spray bar is checked for proper alignment and nozzle angle. The nozzles were set such that the water energy leaving the spray bar would hit the pavement surface at a 30° angle and produce a sweeping motion to literally push the detergent and lifted rubber debris along the airfield surface and out toward the pavement edge.

Figure 17. Water Trailer Pump and Spray Bar Configuration

8.3. Detergent Application Process

The spray bar attached to Toolcat® rear was lowered and locked into position. All control valves were opened to allow for proper detergent flow. The detergent application was initiated by the operator as the spray bar moved directly over the area to be cleaned. The detergent flow rate was constant, so the travel speed directly determined the volume dispensed over the applicable test area. Each detergent had a different application requirement, so special care was taken to ensure proper Toolcat® speed as required by the detergent manufactures guidelines.

To achieve uniform detergent dispersion, the Toolcat® is positioned such that the spray bar end travelled along the 50-ft edge from end to end as shown in Figure 18. This created a 21-ft wide swath width of detergent to the 30-ft wide test surface. The second pass is performed identically in the opposite direction and along the opposite long edge to ensure complete test area coverage. This method resulted in a 12-ft overlap, due to the test layout, of detergents in the test center, which is of little concern, as proper scrubbing patterns physically displace the detergent and spread it evenly throughout the assigned cleaning area.

Figure 18. Toolcat® Applying Detergents to Dampened Test Area

8.4. Detergent Application Detail

8.4.1. JBS Citrus Application

The detergent JBS Citrus was the first of four detergents to be applied to the airfield runway testing site. It was applied at 0045 hours and allowed to sit undisturbed for 25 minutes prior to water dampening and mechanical agitation. The volume of water used for dampening was minimal and only applied to hasten the foaming action produced during agitation. This is not a standard process, but rather implemented as needed to counteract the drying action of the wind and cold weather environment. Any added water was allowed to sit for ten minutes before the agitation process began. JBS Citrus application details and relevant weather conditions during that timeframe are located in Table 8.

Table 8. JBS Citrus Application Information

RUNWAY & LAYOUT DATA SHEET			
Site Information			
Base:	Duke Airfield, Crestview, Florida		
Date:	Friday, January 22, 2010		
Runway:	18/36		
Primary End:	18		
Test Section Data			
Chemical Used:	**JBS Citrus**	Section 1:	1000' - 1050'
Application Rate:	5.2 gal/sec	Section 2:	1075' - 1125'
Test Section Dimension:	30' x 50' (1500 sq. ft.)	Section 3:	1050' - 1200'
Weather Conditions			
Ambient Temp.:	60°F		
Humidity:	100%		
Conditions:	Cloudy/Fog		
Wind:	WSW 8 mph		
Pavement Temp.:	62°F		
Cleaning Schedule			
Chemical Applied:	0:45 hrs		
1st Water Application:	1:10 hrs		
Agitation Start:	1:20 hrs		
Section 1 Rinse:	2:45 hrs		
Section 2 Rinse:	3:45 hrs		
Section 3 Rinse:	4:45 hrs		
Final Runway Rinse:	6:20 hrs		

8.4.2. DC 101 Application

The detergent DC 101 was the second detergent agent to be applied. It was applied the night following the JBS Citrus application at 0030 hours. The details of the application and relevant weather conditions are shown in Table 9.

Table 9. DC 101 Application Information

RUNWAY & LAYOUT DATA SHEET			
Site Information			
Base:	Duke Airfield, Crestview, Florida		
Date:	Saturday, January 23, 2010		
Runway:	18/36		
Primary End:	18		
Test Section Data			
Chemical Used:	**DC 101**	Section 1:	1225' - 1275'
Application Rate:	8.33 gal/sec	Section 2:	1300' - 1350'
Test Section Dimension:	30' x 50' (1500 sq. ft.)	Section 3:	1375' - 1425'
Weather Conditions			
Ambient Temp.:	44°F		
Humidity:	96%		
Conditions:	Clear		
Wind:	Calm		
Pavement Temp.:	56°F		
Cleaning Schedule			
Chemical Applied:	0:30 hrs		
Agitation Start:	1:00 hrs		
Section 1 Rinse:	2:30 hrs		
Section 2 Rinse:	3:30 hrs		
Section 3 Rinse:	4:30 hrs		
Final Runway Soak:	6:20 hrs		

8.4.3. Avion 50 Application

The detergent Avion 50 is the third detergent to be applied. It was applied the day following the DC 101 application at 0830 hours. The details of the application and relevant weather conditions are shown in Table 10.

Table 10. Avion 50 Application Information

RUNWAY & LAYOUT DATA SHEET			
Site Information			
Base:	Duke Airfield, Crestview, Florida		
Date:	Saturday, January 23, 2010		
Runway:	18/36		
Primary End:	18		
Test Section Data			
Chemical Used:	**Avion 50**	Section 1:	1450' - 1500'
Application Rate:	8.33 gal/sec	Section 2:	1525' - 1575'
Test Section Dimension:	30' x 50' (1500 sq. ft.)	Section 3:	1600' - 1650'
Weather Conditions			
Ambient Temp.:	50°F		
Humidity:	98%		
Conditions:	Cloudy		
Wind:	E 9 mph		
Pavement Temp.:	58°F (start); 81°F (finish)		
Cleaning Schedule			
Chemical Applied:	8:30 hrs		
Agitation Start:	8:53 hrs		
Section 1 Rinse:	10:30 hrs		
Section 2 Rinse:	11:30 hrs		
Section 3 Rinse:	12:30 hrs		
Final Runway Rinse:	14:10 hrs		

8.4.4. Hurrisafe Application

The detergent Hurrisafe is the last of the four detergents to be applied during this test regime. It was applied the night following Avion 50 application starting at 0030 hours. The details of the application and relevant weather conditions are shown in Table 11.

Table 11. Hurrisafe Application Information

RUNWAY & LAYOUT DATA SHEET			
Site Information			
Base:	Duke Airfield, Crestview, Florida		
Date:	Monday, January 25, 2010		
Runway:	18/36		
Primary End:	18		
Test Section Data			
Chemical Used:	**Hurrisafe**	Section 1:	1675' - 1725'
Application Rate:	3.33 gal/sec	Section 2:	1750' - 1800'
Test Section Dimension:	30' x 50' (1500 sq. ft.)	Section 3:	1825' - 1875'
Weather Conditions			
Ambient Temp.:	54°F		
Humidity:	100%		
Conditions:	Partly Cloudy		
Wind:	SW 3 mph		
Pavement Temp.:	60°F		
Cleaning Schedule			
Chemical Applied:	0:30 hrs		
Agitation Start:	1:00 hrs		
Section 1 Rinse:	2:30 hrs		
Section 2 Rinse:	3:30 hrs		
Section 3 Rinse:	4:30 hrs		
Final Runway Soak:	5:30 hrs		

8.5. Detergent Rinsing

The entire test area was thoroughly rinsed to remove the loosened rubber material immediately following the agitation effort; Figure 19 illustrates this process. The rinsing process also neutralized the detergent agents. The amount of water needed for this task was detergent dependent. Re-filling of the water trailer was required multiple times over the course of rinsing each test section.

The rinse procedure began at the centerline (or crown) of the airfield and worked outward in a growing pattern until all detergent and excess water had been pushed from the runway and onto the adjacent grassed area. The Toolcat® with broom attachment followed the rinse trailer to ensure removal of any foreign debris and standing water as shown in Figure 20.

Figure 19. Detergent Rinsing Technique

Figure 20. Toolcat® Applying Detergents to Dampened Test Area

To sufficiently neutralize each detergent used, the manufacturer has calculated the volume of water required to reduce the strong pH values to safe levels. Table 12 identifies the water to detergent ratios required for each agent used.

Table 12. Water Requirement for Proper Cleaning of Detergent

Detergent	* Water Requirement (gal)	* Detergent Volume (gal)	Water : Detergent Ratio (gal)
Avion 50	30,000	550	54.5:1
DC-101	12,000	550	21.8:1
Hurrisafe	7,500	220	34.1:1
JBS Citrus	Until Clean	340	Visual Inspection

** For 100,000 square foot pavement surface*

9. POST-CLEANING FRICTION EVALUATION

Upon completion of the mechanical agitation and rinsing effort, a post-cleaning friction evaluation was performed with the GripTester device. Data was collected using the same methodolgy as the pre-cleaning evaluation to allow for direct friction coefficient comparison. Average texture depth measurements were also obtained using the NASA grease smear test.

9.1. Post-Test Friction Data

Post-cleaning friction analysis was conducted at speeds of 40 mph using the GripTester device at a bearing of (130° relative to true north, runs 1-6); the other half were obtained at that bearing angle, plus 180° (310° relative to true north, runs 7-12). Runs were random within the marked test areas, traversing the entire 30-ft wide test width. The GripTester device provided real time friction measurements every two feet along the 875-ft test parameter.

From the recorded data, standard deviation and mean values were determined and a normal distribution curve is plotted for graphical representation. This was important to demonstrate if there is statistically a significant difference in the surface friction after detergent treatment and to compare the performance of each detergent. The average Mu value results from the GripTester are shown in Table 13 and a plot of these averages is shown in Figure 21.

Table 13. Post-Cleaning Average Mu Values (CFME)

Chemical Zones / Agitation Duration		1x Mechanical Agitation Zone							2x Mechanical Agitation Zone						
		Run Number							Run Number						
		1	2	3	4	5	6	Average Mu (μ)	7	8	9	10	11	12	Average Mu (μ)
JBS CITRUS	2 Hr	0.83	0.69	0.69	0.46	0.57	0.58	0.64	0.54	0.49	0.43	0.30	0.36	0.46	0.43
	3 Hr	0.66	0.41	0.42	0.30	0.31	0.34	0.41	0.36	0.35	0.28	0.53	0.30	0.32	0.36
	4 Hr	0.64	0.55	0.70	0.35	0.62	0.38	0.54	0.56	0.46	0.53	0.44	0.49	0.41	0.48
DC 101	2 Hr	0.62	0.38	0.70	0.40	0.51	0.23	0.47	0.59	0.38	0.49	0.39	0.51	0.35	0.45
	3 Hr	0.55	0.40	0.54	0.49	0.39	0.29	0.44	0.55	0.30	0.47	0.21	0.45	0.32	0.38
	4 Hr	0.62	0.36	0.61	0.31	0.47	0.50	0.48	0.59	0.32	0.42	0.30	0.37	0.46	0.41
AVION 50	2 Hr	0.65	0.69	0.66	0.65	0.51	0.67	0.64	0.61	0.48	0.53	0.44	0.47	0.40	0.49
	3 Hr	0.47	0.66	0.58	0.60	0.43	0.55	0.55	0.47	0.41	0.32	0.53	0.27	0.39	0.40
	4 Hr	0.44	0.65	0.40	0.55	0.46	0.51	0.50	0.41	0.53	0.27	0.45	0.27	0.50	0.40
HURRISAFE	2 Hr	0.57	0.60	0.52	0.52	0.55	0.42	0.53	0.36	0.64	0.52	0.57	0.42	0.62	0.52
	3 Hr	0.56	0.65	0.54	0.62	0.56	0.51	0.57	0.39	0.47	0.42	0.50	0.37	0.52	0.45
	4 Hr	0.52	0.60	0.59	0.57	0.38	0.49	0.53	0.41	0.30	0.38	0.31	0.30	0.34	0.34

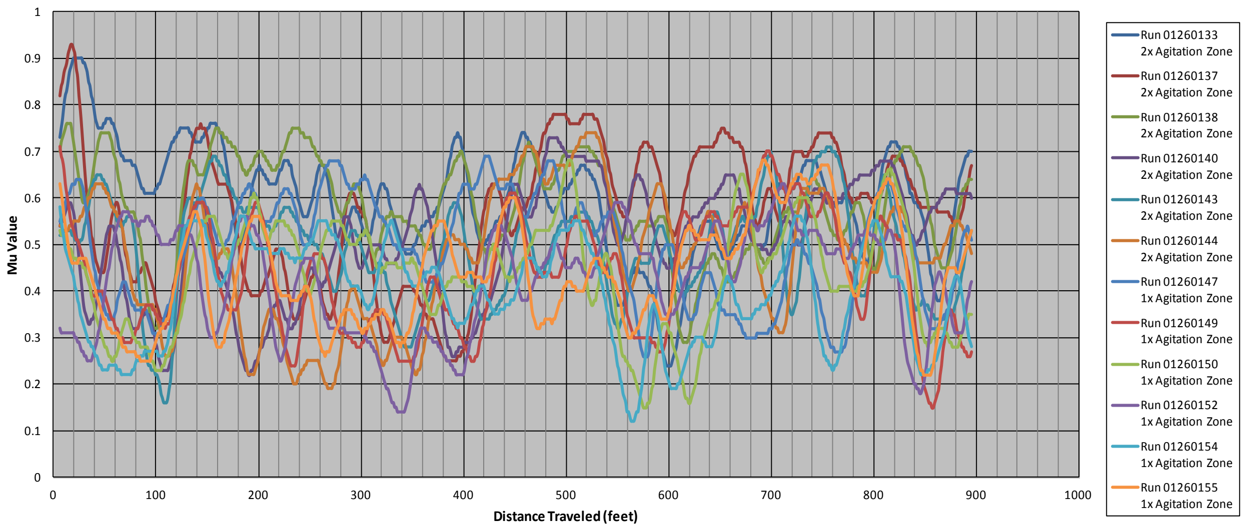


Figure 21. Post-Cleaning Friction Coefficient Data Graph

9.2. Post-Cleaning NASA Grease Smear Test

As with the pre-cleaning evaluation, a second series of NASA Grease Smear Tests were performed to determine the efficiency level of the detergents used and the mechanical effort provided. The post-removal analysis was conducted in the exact manner as the prior series and a direct comparison was made between the two sets of resulting data. Table 14 summarizes and compares the data collected in both pre- and post-series evaluations.

It can be seen from this comparative data that the measured length required to completely exhaust the standard volume of grease and embed it into the airfield macro- texture is much less in the post-analysis testing than in the pre-cleaning routine. All test areas revealed a significant gain in available texture depth after removal of existing rubber. It can be theorized that since the runway was recently resurfaced, some of the fines and binder material were removed from the surface during agitation exposing more of the larger aggregate and creating additional surface voids.

Table 14. Pre/Post-Grease Smear Test Comparison

Site Information	
Base:	Duke Airfield, Crestview, Florida
Date:	1/19/2010 (Pre); 1/26/10 (Post)
Runway:	18/36
Primary End:	18

Texture Measurements - Right of Centerline

Location				**Pre Cleansing**	**Post Cleasing**	
FT From Primary	FT From CTR Line	Pavement Type	Surface Rubber at Test	4" Wide Test Strip Length (in)	4" Wide Test Strip Length (in)	% Change
1025	7.5' R	AC	Light	24.50	23.50	4.08%
1100	7.5' R	AC	Light	33.00	13.50	59.09%
1175	7.5' R	AC	Light	20.00	15.50	22.50%
1250	7.5' R	AC	Light	19.00	15.50	18.42%
1325	7.5' R	AC	Light	26.00	23.00	11.54%
1400	7.5' R	AC	Light	36.00	20.50	43.06%
1475	7.5' R	AC	Light	29.00	16.50	43.10%
1550	7.5' R	AC	Light	22.00	15.50	29.55%
1625	7.5' R	AC	Light	26.25	17.50	33.33%
1700	7.5' R	AC	Light	29.25	14.25	51.28%
1775	7.5' R	AC	Light	21.75	17.00	21.84%
1850	7.5' R	AC	Light	21.50	18.25	15.12%

Texture Measurements - Left of Centerline

Location				**Pre Cleansing**	**Post Cleasing**	
FT From Primary	FT From CTR Line	Pavement Type	Surface Rubber at Test	4" Wide Test Strip Length (in)	4" Wide Test Strip Length (in)	% Change
1025	7.5' L	AC	Light	20.50	16.00	21.95%
1100	7.5' L	AC	Light	26.00	15.00	42.31%
1175	7.5' L	AC	Light	23.00	14.50	36.96%
1250	7.5' L	AC	Light	34.50	15.50	55.07%
1325	7.5' L	AC	Light	19.00	16.00	15.79%
1400	7.5' L	AC	Light	33.00	22.00	33.33%
1475	7.5' L	AC	Light	17.50	16.00	8.57%
1550	7.5' L	AC	Light	30.00	16.00	46.67%
1625	7.5' L	AC	Light	22.50	18.25	18.89%
1700	7.5' L	AC	Light	25.50	18.50	27.45%
1775	7.5' L	AC	Light	30.00	15.25	49.17%
1850	7.5' L	AC	Light	18.00	15.00	16.67%

Table 15 outlines the post-cleaning Grease Smear Test results. The data suggests that cleaning increased overall the texture depths in general. The chart shown in Table 16 represents the hydroplaning potential for specific texture depth ranges. Comparison to pre-cleaning numbers reveals that texture depth at all tested location increased after cleaning.

Table 15. Post-Cleaning Texture Depth

		Right of Centerline			Left of Centerline		
FT From Primary	Vol. of grease (cc)	Grease Area Covered (sq-cm)	Texture Depth (cm)	Hydroplaning Potenial	Grease Area Covered (sq-cm)	Texture Depth (cm)	Hydroplaning Potential
1025	15	606.45	0.025	2	412.90	0.036	3
1100	15	348.39	0.043	3	387.10	0.039	3
1175	15	400.00	0.038	3	374.19	0.040	3
1250	15	400.00	0.038	3	400.00	0.038	3
1325	15	593.55	0.025	2	412.90	0.036	3
1400	15	529.03	0.028	2	567.74	0.026	2
1475	15	425.81	0.035	2	412.90	0.036	3
1550	15	400.00	0.038	3	412.90	0.036	3
1625	15	451.61	0.033	2	470.97	0.032	2
1700	15	367.74	0.041	3	477.42	0.031	2
1775	15	438.71	0.034	2	393.55	0.038	3
1850	15	470.97	0.032	2	387.10	0.039	3

** bearing at 180 degrees*

Table 16. Hydroplaning Potential Chart for use with NASA Grease Smear Testing [3]

Average Texture Depth (ATD)	Hydroplaning Potential
<0.016"	Strong (1)
0.017" - 0.035"	Further Testing Required (2)
>0.036"	Low (3)

9.3. Visual Analysis

Visual inspection of each detergent area is conducted once rinsing is complete and photographs are taken. There was minimal rubber on the runway pre-cleaning; therefore the post-cleaning visuals do not show a significant difference of the amount of rubber on the runway. There is a slight variance from the two different mechanical agitation zones with the amount of rubber removed. The 2x mechanical agitation zones show less rubber left on the runway post-cleaning then the 1x mechanical agitation zones. Based on visual inspection the best result came from the Avion 50 detergent followed by the JBS Citrus, Hurrisafe, and DC 101 detergents. Figure 22–Figure 29 show the post-cleaning condition of each applicable test area by detergent used and orientation relative to the runway bearing.

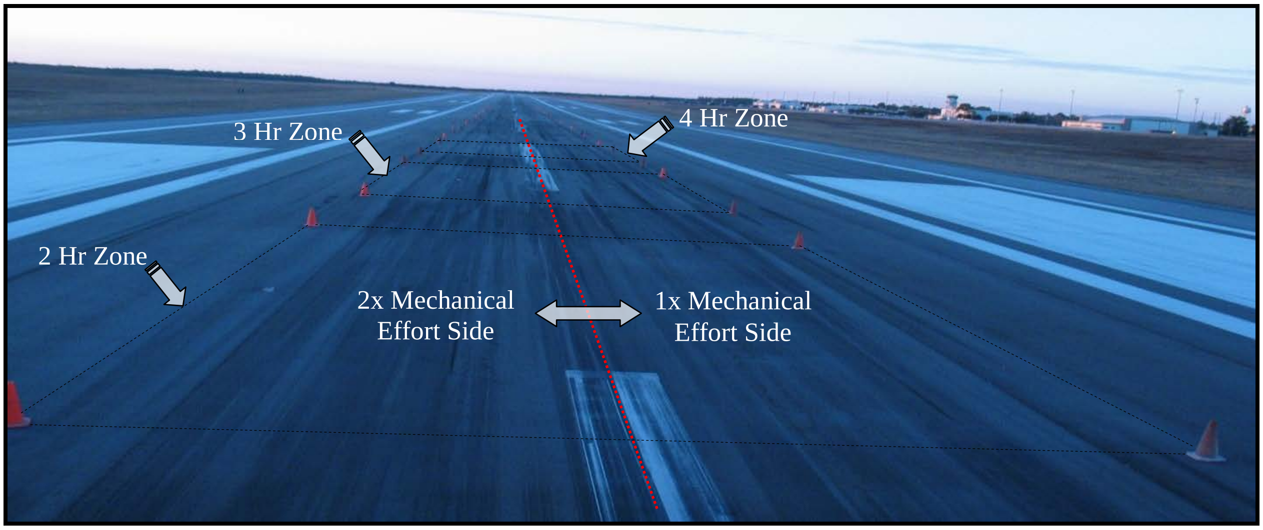


Figure 22. Post-Cleaning Visual – JBS Citrus (18–36)

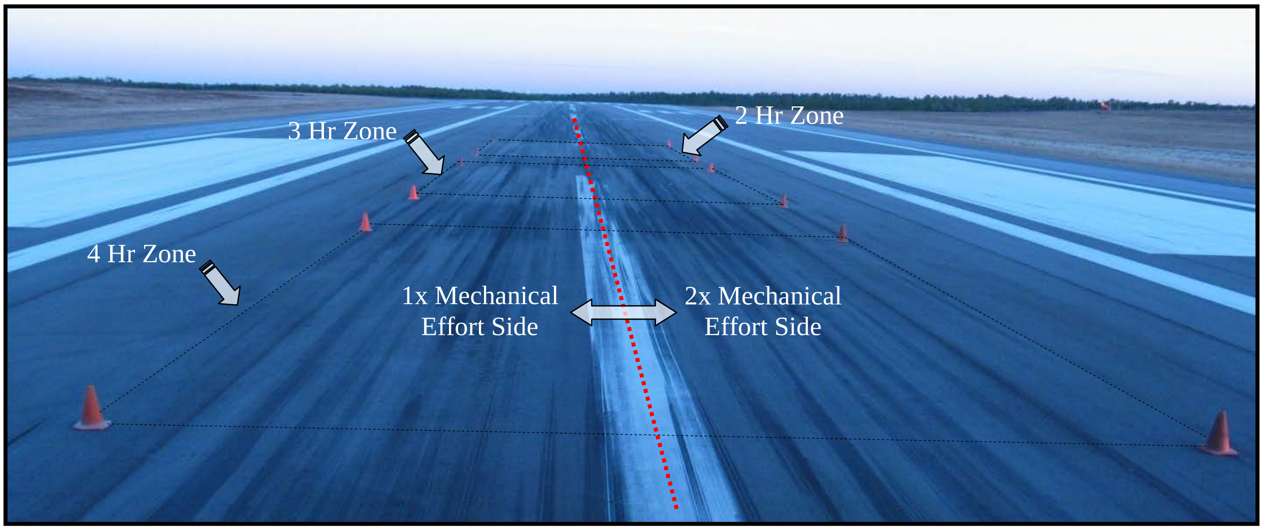


Figure 23. Post-Cleaning Visual – JBS Citrus (36–18)

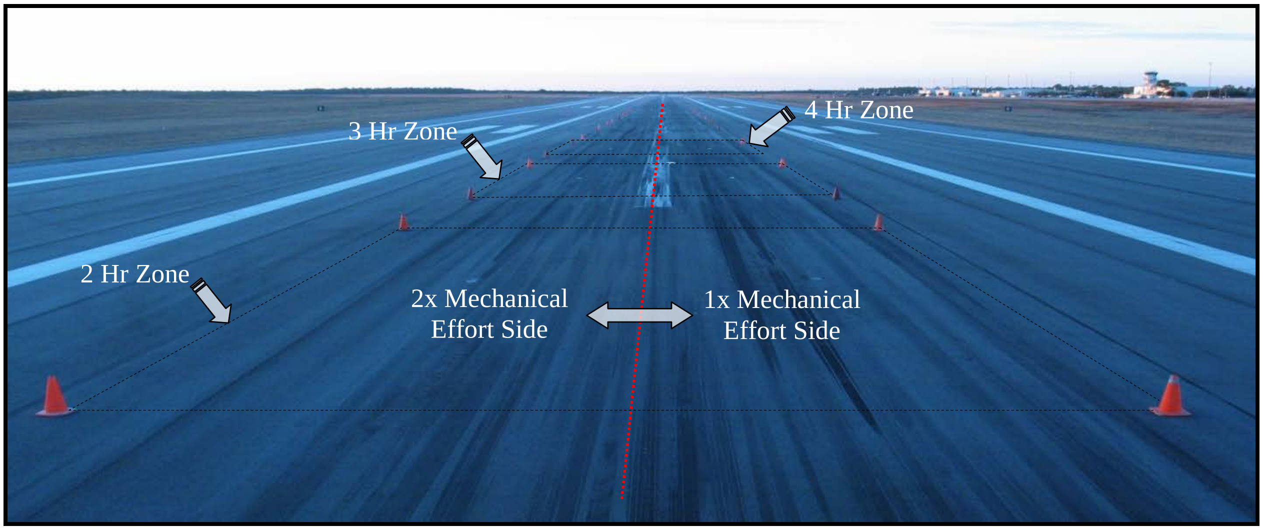


Figure 24. Post-Cleaning Visual – DC 101 (18-36)

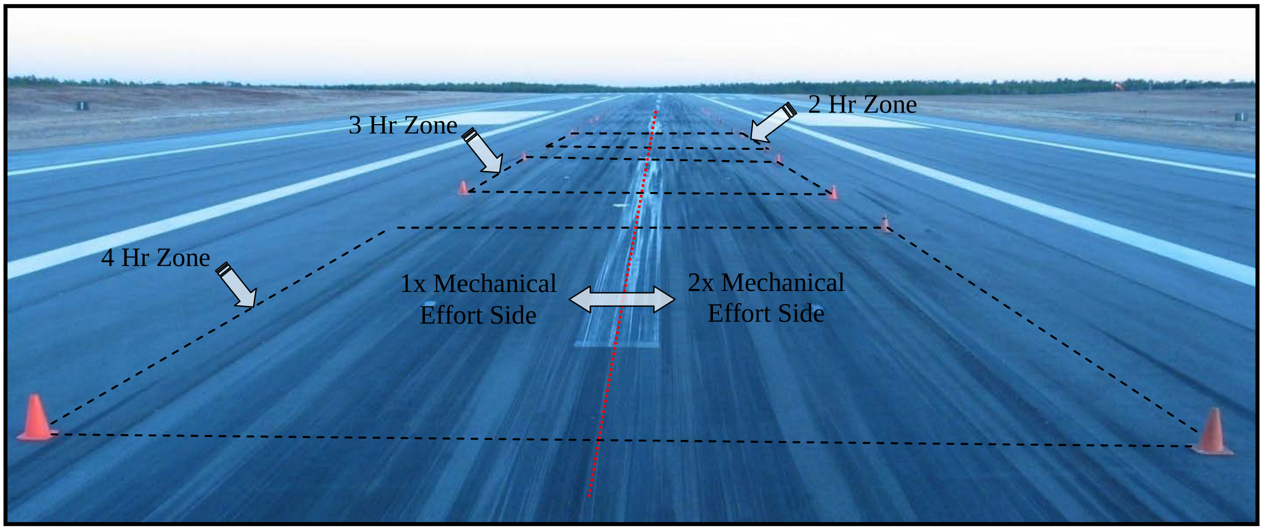


Figure 25. Post-Cleaning Visual – DC 101 (36-18)

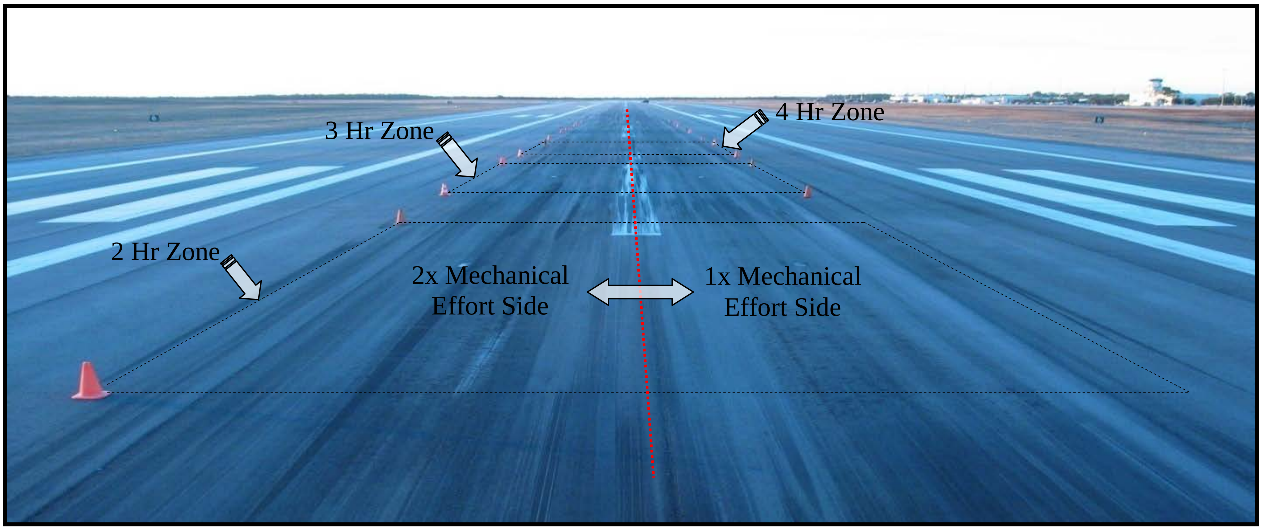


Figure 26. Post-Cleaning Visual – Avion 50 (18-36)

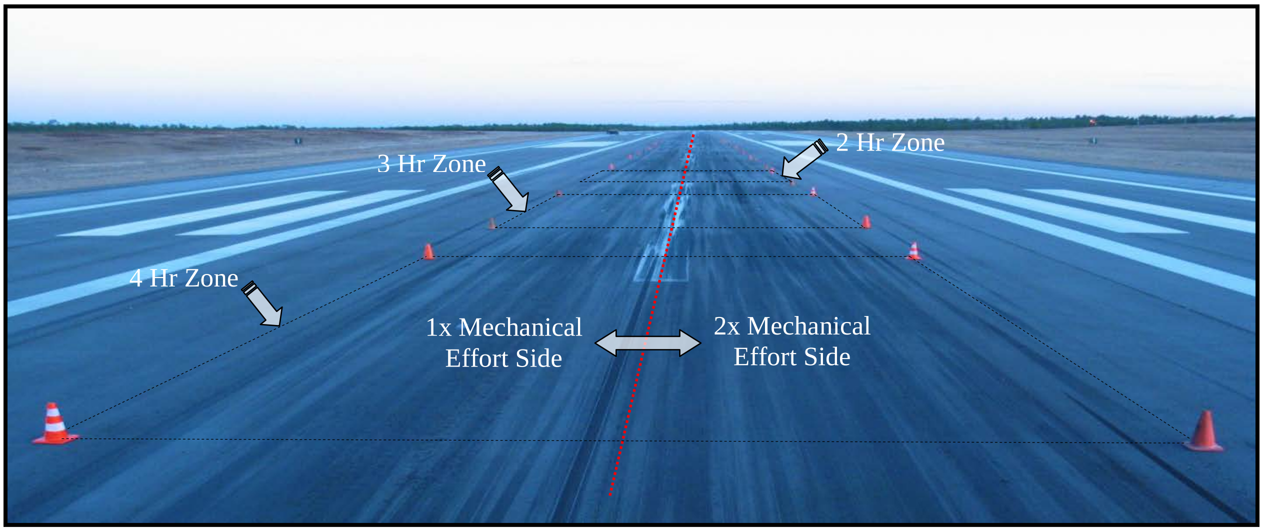


Figure 27. Post-Cleaning Visual – Avion 50 (36-18)

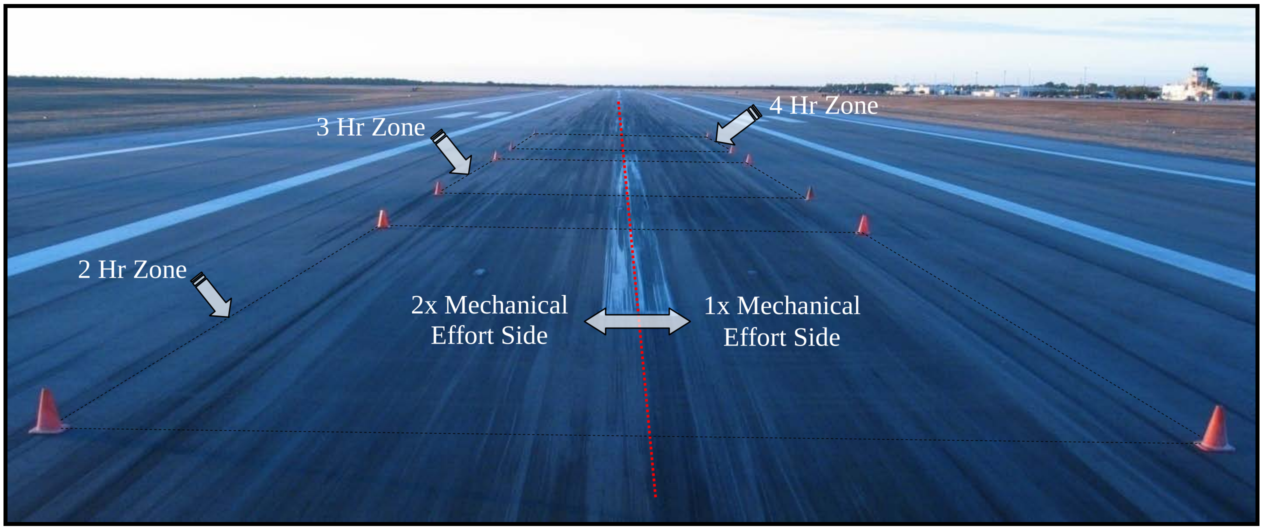


Figure 28. Post-Cleaning Visual – Hurrisafe (18-36)

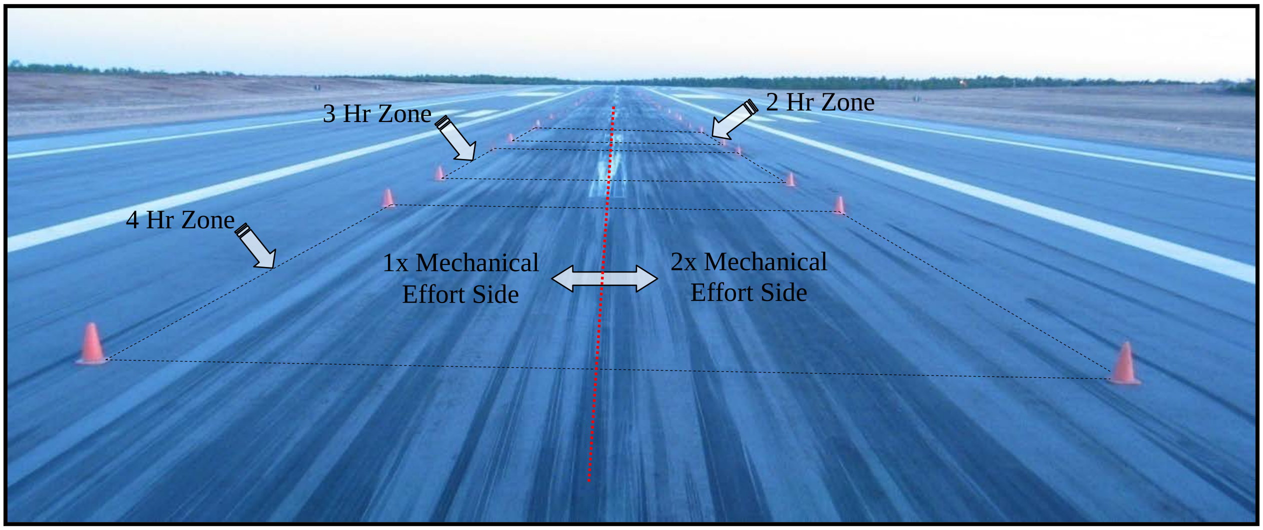


Figure 29. Post-Cleaning Visual – Hurrisafe (36-18)

9.4. Friction Improvement Analysis

Pre- and post-cleaning friction measurement data was compiled and analyzed to determine the overall effects of the removal effort. Table 17 summarizes both pre- and post-cleaning average Mu values and reports the frictional difference by percentage gained or lost after cleaning. The table is divided to compare values by independent detergent and agitation effort and duration.

The data shown reflects that there was a generally slight decrease in available friction after cleaning.

Table 17. Pre/Post-Cleaning Performance Comparison Chart

		2x Mechanical Agitation Zone				1x Mechanical Agitation Zone			
		Pre-Cleansing (Ave. Mu)	Post-Cleansing (Avg. Mu)	Δμ	% Gain/Loss	Pre-Cleansing (Ave. Mu)	Post-Cleansing (Avg. Mu)	Δμ	% Gain/Loss
JBS CITRUS	2 Hr	0.53	0.64	0.10	19.3%	0.42	0.43	0.01	3.0%
	3 Hr	0.47	0.41	(0.06)	-13.0%	0.43	0.36	(0.08)	-17.9%
	4 Hr	0.55	0.54	(0.01)	-2.5%	0.51	0.48	(0.03)	-6.1%
DC 101	2 Hr	0.57	0.47	(0.10)	-17.4%	0.49	0.45	(0.04)	-9.1%
	3 Hr	0.48	0.44	(0.04)	-8.7%	0.48	0.38	(0.09)	-19.0%
	4 Hr	0.58	0.48	(0.11)	-18.2%	0.53	0.41	(0.12)	-22.2%
AVION 50	2 Hr	0.59	0.64	0.05	8.4%	0.54	0.49	(0.05)	-9.2%
	3 Hr	0.50	0.55	0.05	9.4%	0.44	0.40	(0.04)	-8.7%
	4 Hr	0.55	0.50	(0.05)	-8.3%	0.44	0.40	(0.04)	-8.4%
HURRISAFE	2 Hr	0.54	0.53	(0.01)	-2.5%	0.50	0.52	0.02	4.7%
	3 Hr	0.57	0.57	(0.00)	-0.3%	0.48	0.45	(0.04)	-7.3%
	4 Hr	0.47	0.53	0.05	11.6%	0.38	0.34	(0.04)	-11.4%

10. CONCLUSIONS

10.1. Detergent Type

10.1.1. JBS Citrus

The JBS Citrus detergent improved friction of the two hour agitation duration for both the 1x and 2x mechanical agitation zones based on Table 17 using the GripTester. Out of six friction test averages for this detergent, only the two described above showed improvement of friction. The greatest increase in the friction coefficient is for the two hour agitation duration at the 2x mechanical agitation zone which is approximately a 19.3 percent increase.

The NASA Grease Smear test results in Table 14 show the length of the test strip required to completely exhaust the grease and embed it into the macro/micro texture decreased for post-analysis than compared to in pre-analysis. The test areas for the JBS Citrus detergent gained surface voids after the removal of the existing rubber, increasing the average texture depth at these test sections.

This detergent is successful in removing rubber from runways, though after rinsing is completed, dark streaks were left on the pavement surface.

10.1.2. DC 101

The DC 101 detergent did not improve friction on the runway in any of the six friction test averages based on the GripTester data shown on Table 17. The average percent loss for 1x mechanical agitation zone is 16.8% and 14.8% for 2x mechanical agitation zone.

The NASA Grease Smear test shows the average texture depth of the runway increased using the DC 101 detergent. It can be seen on Table 17 the length of the test strip required to completely exhaust the grease and embed it into the macro/micro texture decreased for post-analysis.

10.1.3. Avion 50

The Avion 50 detergent improved friction in two out of a possible six friction test averages based on Table 17. The two gains in friction were located in the 2x mechanical agitation zone for the two hour and three hour agitation durations. The percentage of gain ranged from 8.4% to 9.4%.

The NASA Grease Smear test results in Table 14 show the average texture depth of all the test areas improved in post-analysis using the Avion 50 detergent. The length of the test strip required to completely exhaust the grease and embed it into the macro/micro texture decreased from pre-analysis to post-analysis.

Though Avion 50 has a caustic nature, this detergent out-performed the other three detergents with regards to cleaning efficiency by volume and final visual appearance after rinsing the test area.

10.1.4. Hurrisafe

The Hurrisafe detergent improved friction in two out of a possible six friction test averages based on Table 17 using the GripTester. These increases were located in the 2x mechanical agitation zone with a four hour agitation duration as well as in the 1x mechanical agitation zone for an agitation duration of two hours. The net gain in friction is 11.6% and 4.7%, respectively.

The NASA Grease Smear test shows the friction of the runway increased using the Hurrisafe detergent. Table 14 shows the length of the test strip required to completely exhaust the grease and embed it into the macro/micro texture decreased for post-analysis.

Hurrisafe possessed the best coverage area of all detergents evaluated at 450 sq ft per gallon. It required less rinse water per test area relative to the other detergents evaluated and resulted in a very clean airfield pavement visually.

10.2. Agitation Duration

The detergents for this testing were agitated at three different durations in two different mechanical agitation zones. Table 18 represents the post-cleaning average percentages of gains or losses of friction for each agitation zone at all three agitation durations. The two hour agitation duration overall had the best percentages of friction loss or gain. The only average percentage of friction gain occurred during this duration with the largest deficit of friction is during the three hour duration. The three and four hour agitation duration had similar results.

Table 18. Post-Cleaning Average Friction Gain/Loss

	2x Mechanical Agitation Zone	1x Mechanical Agitation Zone
	Avg. % Gain / Loss of Friction	
2 Hr	2.7	-1.7
3 Hr	-1.4	-12.2
4 Hr	-3.2	-11.2

These results are atypical from what is expected from rubber removal procedures. The two hour duration for the 2x mechanical agitation zone shows a gain in friction whereas the three and four hours show a loss in friction. Theoretically, all three time durations should experience a gain in friction throughout the rubber removal process. The results for this procedure are inconclusive.

10.3. Post-Cleaning Visuals

The post-cleaning visual analysis represents an inconclusive test for all four detergents tested. The existing rubber on the runway before testing is minimal. The pre- and post-cleaning photographs can be seen in Sections 5 and 8, respectively. There is not a significant difference in appearance for the runway.

10.4. Friction Improvement Analysis

The Mu values for post-cleaning should theoretically be higher than the pre-cleaning values. This would represent the friction has increased with the rubber removal process which is the goal in all removal processes. Table 19 represents the percentage of gains / losses of friction from pre-cleaning to post-cleaning as well as the averages for each detergent and duration.

Table 19. Percentage Gain/Loss of Mu Values from Pre- to Post-Cleaning

Gain / Loss of Friction Data Runs

Chemical Zones / Agitation Duration		2x Mechanical Agitation Zone							1x Mechanical Agitation Zone							
		% Gain / Loss of Friction						Avg. % Gain / Loss of Friction	% Gain / Loss of Friction							Avg. % Gain / Loss of Friction
JBS CITRUS	2 Hr	81.0	8.7	16.6	-14.1	20.2	14.5	21.1	12.2	31.6	-17.6	-11.8	-22.5	42.0	3.0	5.3
JBS CITRUS	3 Hr	75.3	-23.9	-1.4	-39.6	-30.7	-34.3	-9.1	-27.0	-7.8	-43.9	61.4	-39.9	-22.1	-17.9	-13.9
JBS CITRUS	4 Hr	3.9	-10.2	45.8	-30.5	-5.6	-16.0	-2.1	-15.5	14.7	-3.2	-9.0	-16.7	3.8	-6.1	-4.6
DC 101	2 Hr	-4.3	-39.2	26.2	-26.6	-17.1	-49.3	-18.4	2.6	-20.0	-9.3	2.2	-9.0	-22.2	-9.1	-9.2
DC 101	3 Hr	5.1	-33.1	15.8	1.5	-19.4	-19.7	-8.3	3.2	-26.5	-10.7	-52.0	-7.2	-28.1	-19.0	-20.0
DC 101	4 Hr	12.5	-38.4	4.7	-51.2	-17.4	-14.4	-17.4	5.6	-40.5	-30.9	-35.5	-27.1	-5.2	-22.2	-22.3
AVION 50	2 Hr	12.7	18.7	13.6	1.2	-11.1	15.9	8.5	9.7	-11.5	-12.1	-5.8	-18.3	-17.3	-9.2	-9.2
AVION 50	3 Hr	7.9	26.9	39.4	-3.5	-11.9	4.3	10.5	-2.2	-8.2	-23.0	39.4	-38.8	-13.3	-8.7	-7.8
AVION 50	4 Hr	5.0	2.0	-20.3	-16.0	-9.3	-9.2	-8.0	-29.0	29.4	-38.5	16.6	-31.2	12.0	-8.4	-7.0
HURRISAFE	2 Hr	6.9	6.6	14.2	-16.9	20.6	-33.2	-0.3	-21.2	6.0	39.7	-3.8	18.1	2.2	4.7	6.5
HURRISAFE	3 Hr	9.9	5.4	16.9	-3.7	4.2	-25.1	1.3	-17.9	-5.6	-16.1	15.9	-22.2	3.9	-7.3	-7.0
HURRISAFE	4 Hr	-4.2	2.4	54.1	47.1	-7.9	-3.8	14.6	-6.2	-32.5	0.3	-17.1	-10.9	2.2	-11.4	-10.8

The average percentages of gains / losses of friction are inconclusive. The data is nonuniform with large gains in some locations and durations and large losses in others. The overall data should consistently show gains in friction with the rubber removed but the majority of the averages show that friction is lost during the process of removal.

The runway at Duke Field had very little rubber build-up prior to cleaning. The build-up would be categorized as very light to light over the entire test section. The impact of this light build-up would be minimal to none as it pertains to the friction loss or gain. So, the data collection does not demonstrate conclusive positive results post cleaning, this is to be expected. Based on data results the only conclusions that were made were visual.

11. REFERENCES

1) McKeen, R.G. and L.R. Lenke, “Alternatives for Runway Rubber Removal from Porous Friction Surfaces”, Air Force Engineering and Services Center, Engineering and Services Center, Tyndall AFB, FL, 1984.

2) U.S. Department of Transportation, “Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces”, *Federal Aviation Administration (FAA) Advisory Circular*, 150/5320-12C, March 18, 1997.

3) Transportation Research Board, “Impact of Rubber Removal Techniques on Runways”, Airport Corporative Research Program Synthesis 11, 2008.

4) International Civil Aviation Organization, Airport Services Manual, “Pavement Surface Conditions Part 2”, Doc 9137-AN/898, Third Edition 1994.

5) International Civil Aviation Organization, “Aerodromes”, Aerodrome Design and Operations Volume 1, First Edition, July 1990.

6) U.S. Department of the Air Force, “Engineering Technical Letter (ETL) 04-10 (Change 1): Determining the Need for Runway Rubber Removal”, May 12, 2004.

7) Department of Defense. “Unified Facilities Criteria (UFC). Pavement Design for Airfields”, UFC 3-260-02, 30 June 2001.

Appendix A: Material Safety Data Sheets (MSDS)

MATERIAL SAFETY DATA SHEET

Product Name: **DC– 101**

24 HOUR EMERGENCY TELEPHONE NUMBER :
CHEMTREC : (800) 424-9300

Prepared By: Saric Solutions, Inc.

Manufacturer
Saric Solutions, Inc.
PO Box 1807 Fuquay-Varina, NC 27526-1807
Telephone: 919-341-2254   Fax: 919-557-7111

Date Issued/Revised: 12/18/2006
Chemical Type: MIXTURE– Runway Rubber Remover
Proprietary Mixture

Hazardous Ingredients
None. There are no exposure limits for the ingredients in this product as recognized by OSHA PEL (Permissible exposure limits) or ACGIH TLV (Threshold Limit Value).

HMIS Rating Physical Properties

Health Hazard 1	Solubility: Total in water	Vapor Density– Heavier than air (air=1)
Flammability 0	pH (concentrate): 8	Vapor Pressure– Comp. to water
Reactivity 0	Odor -Slight	Melting Point– N/A
Personal Protection: B	Boiling point– 212 degrees F	Biodegradation - total, moderate
	Evaporation Rate– Comp. to water	% volatile by volume– N/A

Fire And Explosion Data
Flash Point (°F) Not Determined. Water based product is not flammable during normal use and storage.
Extinguishing Media: Carbon dioxide, foam, and ABC dry powder
Special Fire-Fighting Procedures: Protective clothing and self-contained breathing apparatus should be worn when fighting fires involving chemicals.

Health Hazard Data
Effects of overexposure: There are no known effects of overexposure. However, prolonged skin contact, or inhalation of high concentrations of product vapor or mist may be irritating and could be mildly narcotic. Under normal conditions and with proper chemical hygiene practices, there should be little or no hazard in handling this product.

Toxicological Information (components)
Dermal and Eye Irritation– Slight and temporary (rabbit),
Animal Toxicity– dermal LD 50 (rats), 9,500 mg/kg.
Aquatic Toxicity– Not listed as toxic or hazardous under OSHA, EPA and RCRA guidelines (40 CFR 261.21-261.24)

Reactivity Data
Stability: Stable Hazardous Polymerization : Will not occur
Materials to Avoid: Strong Oxidizing agents. Conditions to Avoid: None Known

Emergency and First Aid Procedures
Inhalation: Remove victim to fresh air. Seek medical attention if symptoms persist.
Eyes: Holding eyelids open flush eyes with running water for at least 15 minutes. Get medical assistance
Skin: Immediately rinse thoroughly with water. Wash contaminated clothing before reuse.
If Swallowed: Do not induce vomiting. If conscious, give lots of water or milk. Seek medical help if victim has adverse symptoms.

Handling Spills or Leaks / Waste Disposal
Steps to Be Taken in Case Spilled material creates slippery conditions. Dike spills with absorbent material and shovel into drums for disposal. Clean spill area with water to remove residuals.
Disposal Method: Dispose of in accordance with all local, state and federal regulations.

Employee Protection
Respiratory Protection: Wear a NIOSH/MSHA approved respirator whenever exposure to fumes or vapors exceeds the TLV of any items identified under the hazardous components section or when excessive exposure to product vapors or mists is possible.
Eye Protection: Appropriate eye protection should always be worn when handling chemicals. It is recommended that NIOSH/MSHA approved glasses be worn when handling this product. Emergency eye wash stations should be available and operational for employees.
Protective Clothing: Clothing suitable to prevent skin contact should be worn. Wash hands before eating or drinking after using chemicals.
Ventilation. Efficient exhaust ventilation should be provided to draw fumes and vapors away from workers to prevent routine inhalation.
Protective Gloves: Chemical resistant gloves should be worn when handling this chemical.

Handling Information
Precaution Measures : Store in a cool, dry place. Keep container closed. Keep away from heat or flames.
Avoid accidental discharge to sewers and natural water. Empty container retains vapor and product residue. Observe all labeled safeguards until cleaned, destroyed or recycled.

Transportation Information
Dot Proper Shipping Name: Non-Hazardous Material Hazard Class and Division: N/A
Freight Class: # 55 Reportable Quantity: N/A Other Labeling Information: Not Regulated

ENVIRONMENTAL/REGULATORY
Toxic Substance Control Act (TSCA) : This material or its components are listed on the TSCA Chemical Substance Inventory
SARA TITLE III, Section 313 : Contains no chemicals that appear in 40 CFR 372 requiring reporting.
CERLA Contains no chemicals that require notification of release of quantities of hazardous substances equal or more than the reportable quantities in 40 CFR 302.4.

End Notes
The product information contained herein, is believed to be accurate as of the date of this MSDS, and is provided without warranty, express or implied, as to the results of the use of this information or the product to which it relates. Recipient assumes all responsibility for the use of this information (alone or in combination with any other product), storage or disposal of the product, including any resulting personal injury or property damage.

Recognize that virtually any chemical (substance) has inherent hazards that can cause harm under the right conditions. Water can drown or burn you, pure oxygen can cause deadly fires, and consuming too much alcohol too quickly will cause fatal poisoning.

PCI OF AMERICA

PCI OF AMERICA
2701 Tower Oaks Blve
Suite 300
Rockville Md 20852

MATERIAL SAFETY DATA SHEET

(301) 468-1700
fax (301) 468-1744

1. IDENTIFICATION

PRODUCT NAME:	HURRISAFE 8035 HK288A HIGH PRESSURE CLEANER/RUNWAY CLEANER		
CHEMICAL NAME:	Alkaline Cleaner	DATE REVISED:	10-Mar-05
DEPARTMENT OF TRANSPORTATION	HAZARD CLASSIFICATION: None SHIPPING NAME: Cleaning Compound, Class 55		

II. PHYSICAL DATA

BOILING POINT,(F)	212F	VAPOR PRESSURE AT 20 C	14.2 mm Hg
SPECIFIC GRAVITY (Water=1)	1.01	WATER SOLUBILITY	Completely
VAPOR DENSITY (air=1)	0.62	DENSITY	8.45O
PERCENT VOLATILE BY VOLUME (%)	N/A	EVAPORATION RATE WATER=1	1. 0
pH (of concentrate)	11.4-12.4	VOC'S (Cal. SCAQMD Rule 1171)	23 gm/l at a 3:1 dilution
APPEARANCE AND ODOR:	Blue in Color, Non-Objectionable odor		

III. INGREDIENTS

MATERIAL	%	OSHAL PEL	TLV (units)	HAZARD
2-butoxyethanol	less than 9%	25ppm	120 mg/m3	N/A
"" CAS # 111-76-2	N/A	N/A	TWA-25ppm	N/A
N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A

IV. FIRE & EXPLOSION HAZARD DATA

FLASH POINT (test method)	None/cc	FLAMMABLE LIMITS: None	LOWER: None	UPPER: None
EXTINGUISHING	N/A	N/A	N/A	
SPECIAL FIRE FIGHTING PROCEDURES	N/A			
UNUSUAL FIRE AND EXPLOSION HAZARDS	N/A			

V. HEALTH HAZARD DATA

TLV AND SOURCE	Not established
ACUTE EFFECTS OF OVEREXPOSURE	Direct eye contact and prolonged or repeated skin contact may cause irritation seen as redness.
SKIN CONTACT	May cause dryness and irritation

EMERGENCY AND FIRST AID PROCEDURES

SWALLOWING:	If swallowed drink warm water to dilute stomach contents, induce vomiting.
SKIN:	Flush thououghly with soap and water. Dry and apply skin lotion.
INHALATION:	None
EYE:	Flush eyes with water for 15 minutes, lifting the lower and upper lids Obtain attention if irritation persists.
NOTES TO PHYSICIAN:	This is relatively innocuous substance not expected to cause harm. Should treatment ever be required, it would be directed at control of symptons.

VI. REACTIVITY DATA

STABILITY	STABLE: Yes	UNSTABLE: No	CONDITIONS TO AVOID None
INCOMPATIBILITY	Avoid oxidizing materials.		
HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS			None
HAZARDOUS POLYMERIZATION	May Occur No	WILL NOT OCCUR Yes	CONDITIONS TO AVOID: None

VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS SPILLED	Small Spills: Flush with water. Large Spills: Absorb with sawdust, sand or earth.
WASTE DISPOSAL METHOD	May be disposed of in sewer system. Consult local state, county or Federal regulations for applicable laws pertaining to your areas.

VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (type):	None
VENTILATION	If desired. Local exhaust is sufficient.
PROTECTIVE GLOVES	Use if long exposure is expected.
EYE PROTECTION	If splashing is expected use goggles
OTHER PROTECTIVE EQUIPMENT	Wear plastic apron if excessive splashing is expected. If clothing becomes soaked, remove, shower, and wash clothing.

IX. SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING	Store in cool dry area. Prevent freezing, if frozen allow to thaw, stir well and re-use.

PCI of America: 2701 Tower Oaks Blvd, Suite 300 Rockville, Md. 20852 (301) 468-1700- Fax (301) 468-1744
Toll: 800 222-1455 or Bobbiepettit@hurrisafe.com

MATERIAL SAFETY DATA SHEET (MSDS)

24 HOUR EMERGENCY PHONE: CHEMTREC 1-800-424-9300

Effective Date: Jan. 1, 2001 / Supersedes: Jan. 1, 2000 / PAGE 1 OF 2

JBS INDUSTRIES

2550 Henkle Drive - Lebanon, Ohio 45036

TELEPHONE: 1-888-745-0720

SECTION 1 PRODUCT & COMPANY IDENTIFICATION

PRODUCT NAME:	**JBS RUNWAY CLEANER CITRUS**	PRODUCT NUMBER:	IJ-401
PRODUCT DESCRIPTION:	LIQUID CITRUS ALKALINE DETERGENT		
MANUFACTURER:	JBS Industries 2550 Henkle Drive Lebanon, Ohio 45036	PHONE: FAX:	**888-745-0720** **513-228-2810**

SECTION 2 COMPOSITION / INFORMATION ON INGREDIENTS

HAZARDOUS INGREDIENTS:	EFFECT	CAS#	PERCENT
SODIUM METASILICATE	CORROSIVE TO EYES	6834-92-0	0-5
CITRUS TERPENE	SKIN & EYE IRRITANT	5989-27-5	0-5
SODIUM TRIPOLYPHOSPHATE	SKIN & EYE IRRITANT	7758-29-4	0-15
PROPRIETARY SURFACTANT BLEND	EYE IRRITANT	NOT APPLICABLE	0-20

HAZARDOUS INGREDIENTS:	EXPOSURE LIMITS OF INGREDIENTS	
	OSHA PEL	ACGIH TLV
SODIUM METASILICATE	NOT ESTABLISHED	NOT ESTABLISHED
CITRUS TERPENE	NOT ESTABLISHED	NOT ESTABLISHED
SODIUM TRIPOLYPHOSPHATE	NOT ESTABLISHED	NOT ESTABLISHED
PROPRIETARY SURFACTANT BLEND	NOT ESTABLISHED	NOT ESTABLISHED

SECTION 3 HAZARDS IDENTIFICATION

>>>>>>>>>>>>>>>>>>>>EMERGENCY OVERVIEW<<<<<<<<<<<<<<<<<<<<

VERY IRRITATING TO EYES. INHALATION OF MISTS MAY BE IRRITATING TO THROAT AND RESPIRATORY TRACT. REPEATED CONTACT WITH SKIN CAN REMOVE NATURAL OILS AND CAUSE DRYNESS AND IRRITATION.

>>>>>>>>>>>>>>>>>>>>>>>>>>>>>><<<<<<<<<<<<<<<<<<<<<<<<<<<<<<

SECTION 4 FIRST AID MEASURES

EYES:	FLUSH WITH CLEAR WATER FOR AT LEAST 15 MINUTES. GET IMMEDIATE MEDICAL ATTENTION.
SKIN:	RINSE WELL WITH WATER. REMOVE CONTAMINATED CLOTHING.
INGESTION:	GIVE WATER IF CONSCIOUS. DO NOT INDUCE VOMITING, ALTHOUGH VOMITING MAY OCCUR NATURALLY. GET IMMEDIATE MEDICAL ATTENTION.
INHALATION:	MOVE TO FRESH AIR. IF IRRITATION PERSISTS, GET MEDICAL ATTENTION.

SECTION 5 FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES:	FLASH POINT:	NONE
	METHOD USED:	NOT APPLICABLE

PRODUCT WILL NOT BURN. NO KNOWN HAZARDOUS DECOMPOSITION PRODUCTS.
UNUSUAL FIRE & EXPLOSION HAZARDS: UPON CONTACT WITH DUSTS OF AL, SN, OR ZN, MAY PRODUCE HYDROGEN GAS, WHICH IS FLAMMABLE.
FIRE FIGHTING PROCEDURES: APPROPRIATE FOR SURROUNDING MATERIALS.

SECTION 6 ACCIDENTAL RELEASE MEASURES

SPILLS & LEAKS:	SMALL SPILLS: RINSE TO DRAIN. LARGE SPILLS: CONTAIN FOR RECLAMATION OR DISPOSAL.
CAUTION:	SPILLS OF THIS MATERIAL MAY CAUSE FLOOR TO BECOME SLIPPERY.

SECTION 7 HANDLING & STORAGE

STORE IN ORIGINAL CONTAINER AT TEMPERATURES BELOW 120 DEGREES F.
PRODUCT IS BEST WHEN USED WITHIN 6 MONTHS OF DATE OF PURCHASE.

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EYES:	WEAR CHEMICAL GOGGLES.
SKIN:	NEOPRENE GLOVES. RUBBER APRON IF GREATER EXPOSURE IS LIKELY.
RESPIRATORY:	GOOD GENERAL VENTILATION. RESPIRATOR NOT NORMALLY REQUIRED.

SECTION 9 PHYSICAL & CHEMICAL PROPERTIES

APPEARANCE & ODOR: THIN CLEAR LIQUID WITH CITRUS FRAGRANCE.
SOLUBILITY IN WATER: COMPLETE
% VOLATILE (W/W): >85, MOSTLY WATER FREEZING POINT: NEAR WATER.
PH FULL STRENGTH: 9.0 TO 10 .5 SPECIFIC GRAVITY: 1.08

SECTION 10 STABILITY & REACTIVITY

STABILITY: THIS IS A STABLE MATERIAL.
CONDITIONS TO AVOID: NONE KNOWN.
MATERIALS TO AVOID: STRONG ACIDS, DUSTS OF ALUMINUM, TIN AND ZINC.
HAZARDOUS POLYMERIZATION WILL NOT OCCUR.

SECTION 11 TOXICOLOGICAL INFORMATION

NO DATA AVAILABLE ON THIS MIXTURE. FOR INFORMATION ON INGREDIENTS, WRITE TO THE ADDRESS LISTED IN SECTION 1 OF THIS MSDS.

SECTION 12 ECOLOGICAL INFORMATION

NO DATA AVAILABLE ON THIS MIXTURE. ALL SURFACTANT COMPONENTS ARE BIODEGRADABLE. THIS PRODUCT CONTAINS PHOSPHATES.

SECTION 13 DISPOSAL CONSIDERATIONS

FOLLOW ALL FEDERAL, STATE, AND LOCAL REGULATIONS APPROPRIATE FOR THIS MATERIAL. NEUTRALIZE PH WITH DILUTED ACID BEFORE DISPOSAL.

SECTION 14 TRANSPORTATION INFORMATION

D.O.T. HAZARDOUS MATERIAL CLASS: NOT A D.O.T. HAZARDOUS MATERIAL.
UN NUMBER: NOT APPLICABLE NA NUMBER: NOT APPLICABLE

SECTION 15 REGULATORY INFORMATION

FACILITIES STORING MORE THAN 38,000 GALLONS OF THIS MATERIAL MUST FILE A SARA TITLE III FOR SODIUM HYDROXIDE

SECTION 16 OTHER INFORMATION

HAZARD RATINGS PROVIDED FOR USE BY TRAINED INDIVIDUALS ONLY.
HMIS RATINGS (0=MINIMAL, 1=SLIGHT, 2=MODERATE, 3=SERIOUS, 4=SEVERE HAZARD)
FOR CONCENTRATE: HEALTH: 3 FLAMMABILITY: 0 REACTIVITY: 0

NFPA RATINGS (0=MINIMAL, 1=SLIGHT, 2=MODERATE, 3=SERIOUS, 4=SEVERE HAZARD)
FOR CONCENTRATE: HEALTH: 3 FLAMMABILITY: 0 REACTIVITY: 0
DILUTION OVER 30 TO 1: HEALTH: 2 FLAMMABILITY: 0 REACTIVITY: 0

JBS INDUSTRIES a Division of Mix Masters, Inc. 2550 HENKLE DRIVE LEBANON, OH 45036, 888-745-0720

MATERIAL SAFETY DATA SHEET (MSDS)

24 HOUR EMERGENCY PHONE: CHEMTREC 1-800-424-9300

Effective Date: Sept. 1, 2004 / Supersedes: Jan. 1, 2000 / PAGE 1 OF 2

JBS INDUSTRIES

2550 Henkle Drive - Lebanon, Ohio 45036

TELEPHONE: 1-888-745-0720

SECTION 1 PRODUCT & COMPANY IDENTIFICATION

PRODUCT NAME:	FINAL APPROACH	PRODUCT NUMBER:	AV-175
PRODUCT DESCRIPTION.	CITRUS SOLVENT COATING REMOVER		
MANUFACTURER:	JBS Industries 2550 Henkle Drive Lebanon, Ohio 45036	PHONE: FAX:	888-745-0720 513-228-2810

SECTION 2 COMPOSITION / INFORMATION ON INGREDIENTS

HAZARDOUS INGREDIENTS:	EFFECT	CAS#	PERCENT
CITRUS TERPENE	SKIN & EYE IRRITANT	5989-27-5	0-70
2-BUTOXYETHANOL	EYE IRRITANT	111-76-2	0-5
PROPRIETARY SURFACTANT BLEND	EYE IRRITANT	NOT APPLICABLE	0-20

HAZARDOUS INGREDIENTS:	EXPOSURE LIMITS OF INGREDIENTS	
	OSHA PEL	ACGIH TLV
CITRUS TERPENE	NOT ESTABLISHED	NOT ESTABLISHED
2-BUTOXYETHANOL	25 ppm (SKIN)	25 ppm (SKIN)
PROPRIETARY SURFACTANT BLEND	NOT ESTABLISHED	NOT ESTABLISHED

SECTION 3 HAZARDS IDENTIFICATION

>>>>>>>>>>>>>>>>>>>>**EMERGENCY OVERVIEW**<<<<<<<<<<<<<<<<<<<

CAN BE CORROSIVE TO EYES. INHALATION OF MISTS MAY BE IRRITATING TO THROAT AND RESPIRATORY TRACT. MAY CAUSE IRRITATION TO SKIN WITH PROLONGED EXPOSURE.

>>>>>>>>>>>>>>>>>>>>>>>>>>>><<<<<<<<<<<<<<<<<<<<<<<<<<<<<<

SECTION 4 FIRST AID MEASURES

EYES:	FLUSH EYES WITH LARGE QUANTITIES OF WATER, HOLDING EYELIDS OPEN FOR AT LEAST 15 MINUTES. GET IMMEDIATE MEDICAL ATTENTION.
SKIN:	REMOVE CONTAMINATED CLOTHING. WASH WITH SOAP AND WATER. SEEK MEDICAL ATTENTION IF IRRITATION PERSISTS.
INGESTION:	GIVE WATER IF CONSCIOUS. DO NOT INDUCE VOMITING, ALTHOUGH VOMITING MAY OCCUR NATUARALLY. GET IMMEDIATE MEDICAL ATTENTION.
INHALATION:	MOVE TO FRESH AIR. IF IRRITATION PERSISTS, GET MEDICAL ATTENTION.

SECTION 5 FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES:	FLASH POINT:	110 F
	METHOD USED:	NOT APPLICABLE

PRODUCT IS MOSTLY WATER AND WILL NOT BURN. INCOMPLETE COMBUSTION OF VAPORS MAY PRODUCE CARBON MONOXIDE, WHICH IS POISONOUS.

UNUSUAL FIRE & EXPLOSION HAZARDS: NONE KNOWN

FIRE FIGHTING PROCEDURES: APPROPRIATE FOR SURROUNDING MATERIALS.

SECTION 6 ACCIDENTAL RELEASE MEASURES

SPILLS & LEAKS:	SMALL SPILLS: RINSE TO DRAIN. LARGE SPILLS: CONTAIN FOR RECLAMATION OR DISPOSAL.
CAUTION:	SPILLS OF THIS MATERIAL MAY CAUSE FLOOR TO BECOME SLIPPERY.

SECTION 7 HANDLING & STORAGE

PRODUCT SHOULD BE STORED IN ORIGINAL CONTAINERS AT TEMPERATURES BELOW 120 DEGREES F.
PRODUCT SHELF LIFE IS APPROXIMATELY 6 MONTHS.

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EYES:	WEAR CHEMICAL GOGGLES.
SKIN:	SOLVENT PROOF GLOVES. RUBBER APRON IF GREATER EXPOSURE IS LIKELY.
RESPIRATORY:	GOOD GENERAL VENTILATION. RESPIRATOR NOT NORMALLY REQUIRED.

SECTION 9 PHYSICAL & CHEMICAL PROPERTIES

APPEARANCE & ODOR: THIN AMBER LIQUID WITH CHARACTERISTIC CITRUS ODOR.
SOLUBILITY IN WATER: EMULSION
% VOLATILE (W/W): >75, MOSTLY WATER FREEZING POINT: NEAR WATER.
PH FULL STRENGTH: 9.0 SPECIFIC GRAVITY: 1.00

SECTION 10 STABILITY & REACTIVITY

STABILITY: THIS IS A STABLE MATERIAL.
CONDITIONS TO AVOID: NONE KNOWN.
MATERIALS TO AVOID: STRONG OXIDIZING AGENTS.
HAZARDOUS POLYMERIZATION WILL NOT OCCUR.

SECTION 11 TOXICOLOGICAL INFORMATION

NO DATA AVAILABLE ON THIS MIXTURE. FOR INFORMATION ON INGREDIENTS, WRITE TO THE ADDRESS LISTED IN SECTION 1 OF THIS MSDS.

SECTION 12 ECOLOGICAL INFORMATION

NO DATA AVAILABLE ON THIS MIXTURE. ALL SURFACTANT COMPONENTS ARE BIODEGRADABLE. THIS PRODUCT **DOES NOT** CONTAIN PHOSPHATES.

SECTION 13 DISPOSAL CONSIDERATIONS

FOLLOW ALL FEDERAL, STATE, AND LOCAL REGULATIONS APPROPRIATE FOR THIS MATERIAL.

SECTION 14 TRANSPORTATION INFORMATION

D.O.T. HAZARDOUS MATERIAL CLASS: NOT A D.O.T. HAZARDOUS MATERIAL.
UN NUMBER: NOT APPLICABLE NA NUMBER: NOT APPLICABLE

SECTION 15 REGULATORY INFORMATION

THIS MATERIAL IS NOT SARA TITLE III REPORTABLE.

SECTION 16 OTHER INFORMATION

HAZARD RATINGS PROVIDED FOR USE BY TRAINED INDIVIDUALS ONLY.
HMIS RATINGS (0=MINIMAL, 1=SLIGHT, 2=MODERATE, 3=SERIOUS, 4=SEVERE HAZARD)
FOR CONCENTRATE: HEALTH: 1 FLAMMABILITY: 2 REACTIVITY: 0

NFPA RATINGS (0=MINIMAL, 1=SLIGHT, 2=MODERATE, 3=SERIOUS, 4=SEVERE HAZARD)
FOR CONCENTRATE: HEALTH: 1 FLAMMABILITY: 2 REACTIVITY: 0
DILUTION OVER 30 TO 1: HEALTH: 1 FLAMMABILITY: 1 REACTIVITY: 0

JBS INDUSTRIES a Division of Mix Masters, Inc. 2550 HENKLE DRIVE LEBANON, OH 45036, 888-745-0720

MATERIAL SAFETY DATA SHEET (MSDS)

Meets The Requirements of 29CFR1910

CHEMTEK INCORPORATED
INFORMATION (800)672-8536
CHEMICAL EMERGENCY (800)535-5053
Box 86 - Yanceyville, N.C. 27379 USA

HMIS DESIGNATION
HEALTH: 3 FIRE: 0 REACTIVITY: 0

IDENTIFICATION

TRADE NAME: AVION 50 **SYNONYMS: Runway Cleaner**

Department of Transportation Classification:
Corrosive Liquid, basic, Inorganic, N.O.S., 8, UN3266, II, (Contains Sodium Hydroxide)

NMFA: Cleaning, Scouring Washing Compounds, NOI or Soap Liquid, ITEM 48580 Sub 3, Class 55

SAFE HANDLING PROCEDURES

Precautions To Be Taken In Handling And Storage: WARNING: Harmful or Fatal if Swallowed. May Cause Burns. Provide Sufficient Ventilation To Maintain Exposure Below TLV By Avoiding Mists. Normal use of this material does not expose the user to concentrations exceeding the respiratory TLV. Avoid skin and eye contact. Avoid contact with reactive metals and acid solutions. Always store unused portion in original container with cap secure.

PROTECTIVE EQUIPMENT

EYES: Splash-Proof Goggles,
Full Face Shield if Splashing Likely

SKIN: Rubber Gloves if Contact Likely

VENTILATION REQUIREMENTS
Provide Sufficient Ventilation to Maintain Exposure Below Recommended TLV(S)

RESPIRATORY
Use NIOSH approved Respirator: Full face if concentration exceeds TLV(S)

SPECIAL CLOTHING/EQUIPMENT:
Plastic Apron and Rubber Boots if Contact With Concentrate Likely. Otherwise, No Special Clothing Required.

HAZARDOUS COMPONENTS AS DEFINED BY THE STANDARD

CHEMICAL MATERIAL	OSHA TLV	NIOSH	EYES	SKIN	SARA III SECT 313
SODIUM HYDROXIDE	2 mg/m^3	2 mg/m^3	1% SEV-rbt	50mg SEV	No

Please Note: Judgement Is Based On Indirect Test Data

FIRE, EXPLOSION AND REACTIVITY DATA

FLASHPOINT: None **METHOD:** Indirect
FLAMMABLE EXPLOSIVE LIMITS (AIR) - LEL: Not Applicable **UEL:** Not Applicable
EXTINGUISHING MEDIA: Dry Foam, Chemical, CO2, Water Fog
SPECIAL HAZARDS - FIRE FIGHTING PROCEDURES: Self Contained Breathing Apparatus.
HAZARDOUS DECOMPOSITION PRODUCTS: When heated to decomposition, emits acrid smoke and irritating fumes.
MATERIAL IS STABLE Y **HAZARDOUS POLYMERIZATION** NO
CONDITIONS TO AVOID: Extreme heat or pressure.
INCOMPATIBILITY: (MATERIALS TO AVOID) Acid Solutions, HCl, Reactive Metals, Strong Oxidizers

HEALTH HAZARD DATA

PRIMARY ROUTES OF EXPOSURE: INHALATION YES SKIN CONTACT YES SKIN ABSORPTION YES INGESTION UNLIKELY EYES YES

EFFECTS OF OVEREXPOSURE: (ACUTE AND CHRONIC)
INHALATION: Inhalation of mist may cause burns of the upper respiratory tract. Headache, dizziness, possible choking, nausea, possible unconsciousness if vapor concentration exceeds TLV.
SKIN CONTACT: May cause burns.
INGESTION: Serious damage to the mucous membranes with perforation or scarring.
EYES: Causes small burns - Corrosive to delicate tissue.
MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Existing dermatitis may be aggravated by exposure to this product.
CHRONIC: Prolonged contact has a destructive effect upon tissue.

TOXICOLOGY: CONTAINS NO CARCINOGENS AS DETERMINED BY THE STANDARD.

EMERGENCY FIRST AID PROCEDURES:

EYES: Flush with water for at least 15 minutes. Get immediate medical attention.
SKIN: Immediately remove clothing, flush with plenty of water. If chemical burn develops as a result of long term exposure, see a physician.
INHALATION: Remove to fresh air. If irritation persists, see a physician.
INGESTION: Give plenty of milk or water. DO NOT INDUCE VOMITING. CALL A PHYSICIAN IMMEDIATELY. Never give anything to drink to an unconscious person.

CONTROL PROCEDURES - SPILL, LEAKAGE OR DISPOSAL

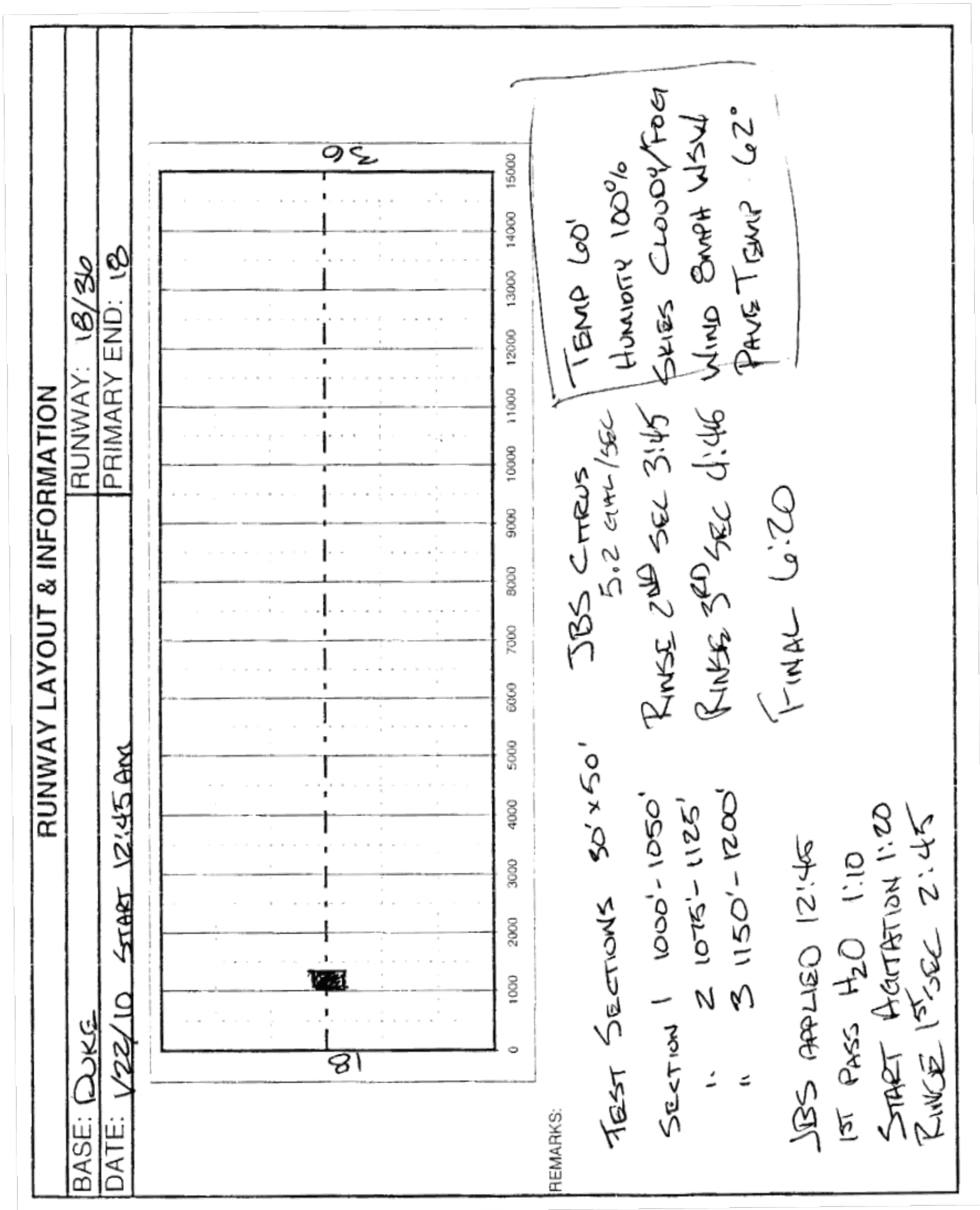
STEPS TO BE TAKEN IF MATERIAL IS SPILLED: Dilute well with water, then absorb in cloth or neutralize with dilute acid and flush to sewer.
WASTE DISPOSAL METHOD:
DISPOSE IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS.

PHYSICAL DATA

pH:>13
BOILING POINT:212EF + 5EF
VAPOR DENSITY:(AIR=1) > 1
EVAPORATION RATE:(ETHER=1) <1
APPEARANCE AND ODOR: Yellow-Green Liquid/Sweet Odor
FREEZING POINT: 0EF ∀ 5EF.
SOLUBILITY IN WATER: Complete

DATE OF PREPARATION:07-03-87 **REVISED:**1-01-95 (4) **PREPARED BY:**

Appendix B: Detergent Application and Layout Sheets: Field Notes



RUNWAY LAYOUT & INFORMATION

BASE: DUKE

RUNWAY: 18/36

DATE: 1/22/10 START 12:45 AM

PRIMARY END: 18

REMARKS:

TEST SECTIONS 50' x 50'

SECTION 1 1000'-1050'

" 2 1075'-1125'

" 3 1150'-1200'

JBS APPLIED 12:46

1ST PASS H_2O 1:10

START AGITATION 1:20

RINSE 1ST SEC 2:45

JBS CITRUS 5.2 GAL/SEC

RINSE 2ND SEC 3:45

RINSE 3RD SEC 4:46

FINAL 6:20

TEMP 60°

HUMIDITY 100%

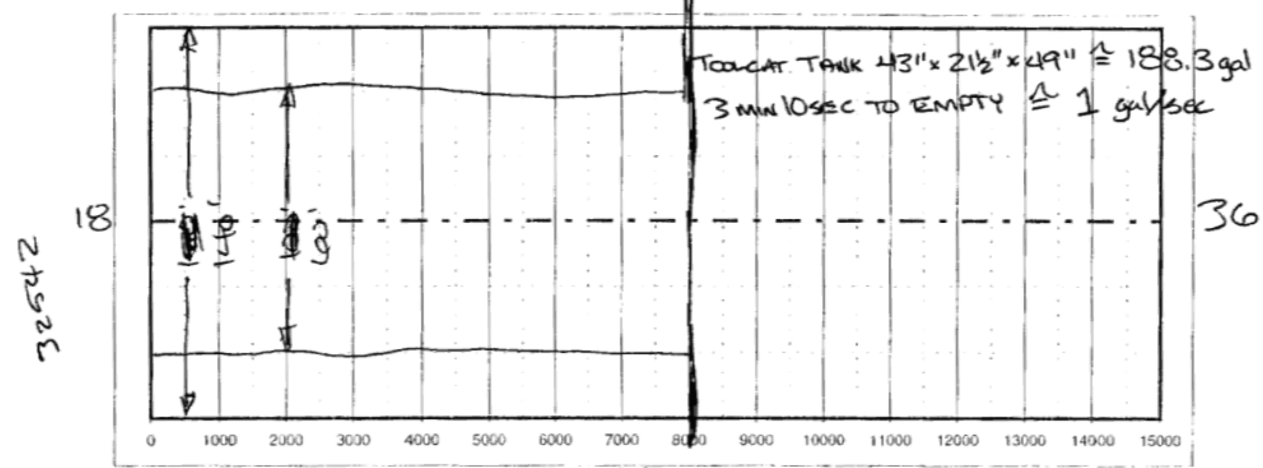
SKIES CLOUDY/FOG

WIND 8MPH WSW

PAVE TEMP 62°

RUNWAY LAYOUT & INFORMATION

BASE: DYKE	RUNWAY: 18/36
DATE: 1/23/10 START 12:30 AM SAT	PRIMARY END: 18



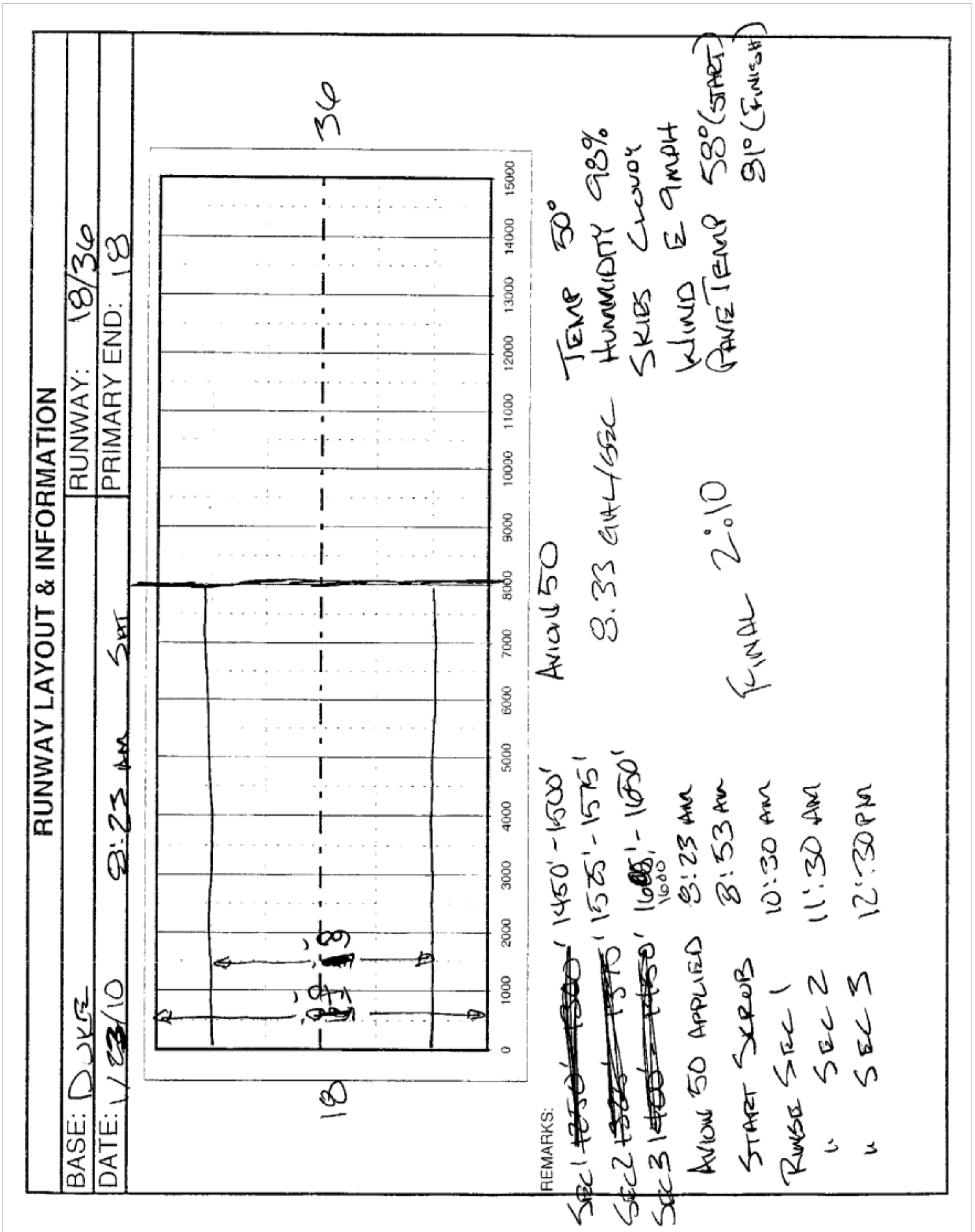
REMARKS:

SEC 1 1225' - 1275'
SEC 2 1300' - 1350'
SEC 3 1375' - 1425'
DC 101 APPLIED 12:30
START SCRUB 1:00
RINSE SEC 1 2:30
RINSE SEC 2 3:30
RINSE SEC 3 4:30

DC 101 8.33 GAL/SEC

FINAL RINSE 6:20

TEMP 44°
HUMIDITY 96%
SKIES CLEAR
WIND CALM
PAVE TEMP 56°

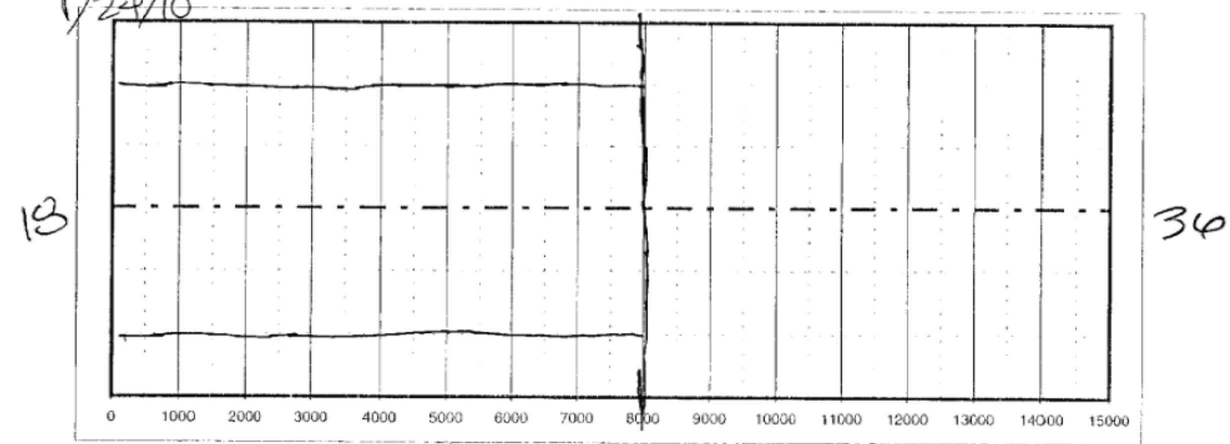

RUNWAY LAYOUT & INFORMATION
BASE: DUKE
DATE: 1/23/10 8:23 AM SAT
RUNWAY: 18/36
PRIMARY END: 18
18
36
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000
REMARKS:
SEC 1 1450'-1500'
SEC 2 1525'-1575'
SEC 3 1600'-1650'
AVION 50 APPLIED 8:23 AM
START SCRUB 8:53 AM
RINSE SEC 1 10:30 AM
" SEC 2 11:30 AM
" SEC 3 12:30 PM
AVION 50
8.33 GAL/SEC
FINAL 2:10
TEMP 50°
HUMIDITY 98%
SKIES CLOUDY
WIND E 9 MPH
PAVE TEMP 58° (START)
31° (FINISH)

RUNWAY LAYOUT & INFORMATION

BASE: DOVR | RUNWAY: 18/36

DATE: 1/24/10 12:30 AM Mon | PRIMARY END: 18

1/24/10



REMARKS:

SEC 1 1675'-1725'

SEC 2 1750'-1800'

SEC 3 1825'-1875'

HURRISAFE APPLIED 12:30AM

START SCRUB 1:00

RINSE SEC 1 2:30

" SEC 2 3:30

" SEC 3 4:30

HURRISAFE

3.33 GAL/SEC

FINAL 5:30

TEMP 54°

HUMIDITY 100%

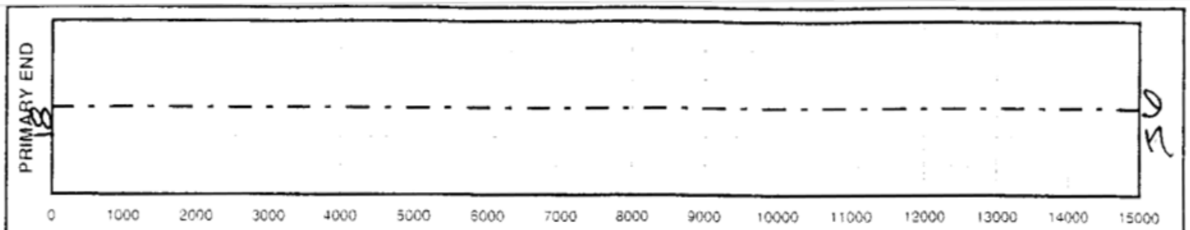
SKIES PARTLY CLOUDY

WIND 3MPH SW

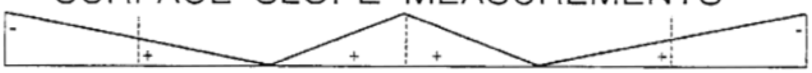
PAVE TEMP 60°

DISTRIBUTION STATEMENT A: Approved for public release; distribution unlimited.
88ABW-2013-2269, 13 May 2013

Appendix C: Airfield Surface Slope Measurements: Field Notes



SURFACE SLOPE MEASUREMENTS

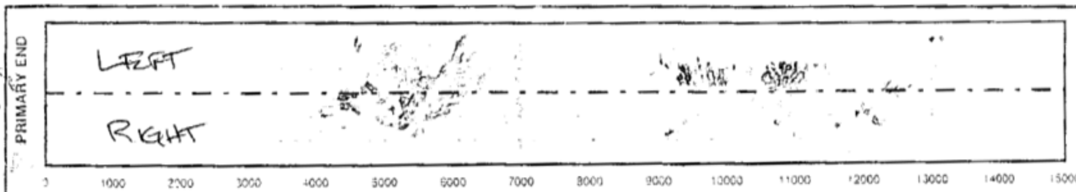


BASE: DUKE	RUNWAY: 18/36
DATE: 1/19/10	PRIMARY END: 18

	DIST		LONG R ~~RT EDGE~~	RT CENT	LT CENT	LONG L ~~LT EDGE~~	~~LONG~~
1	1025	0	+ .1	+ .8	+ .7	+ .2	.
2	1100	500	+ .4	+ 1.4	+ .9	+ .4	.
3	1175	1000	+ .4	+ 1.1	+ 1.0	+ .5	.
4	1250	1500	+ .5	+ .2	+ 1.4	+ .6	.
5	1325	2000	+ .3	+ .1	+ 1.4	+ .3	.
6	1400	2500	+ .2	+ .4	+ 1.3	+ .1	.
7	1475	3000	+ .2	+ .7	+ .9	0.0	.
8	1550	3500	+ .3	+ 1.3	+ .6	+ .2	.
9	1625	4000	+ .2	+ 1.2	+ .7	+ .2	.
10	1700	4500	+ .3	+ .8	+ 1.0	+ .3	.
11	1775	5000	+ .3	+ .6	+ 1.1	+ .4	.
12	1850	5500	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	+ .2	.
		6000	+ .2	+ .4	+ 1.1	.	.
		6500	.	.	.	.	.
		7000	.	.	.	.	.
		7500	.	.	.	.	.
		8000	.	.	.	.	.
		8500	.	.	.	.	.
		9000	.	.	.	.	.
		9500	.	.	.	.	.
		10000	.	.	.	.	.
		10500	.	.	.	.	.
		11000	.	.	.	.	.
		11500	.	.	.	.	.
		12000	.	.	.	.	.
		12500	.	.	.	.	.
		13000	.	.	.	.	.
		13500	.	.	.	.	.
		14000	.	.	.	.	.
		14500	.	.	.	.	.
		15000	.	.	.	.	.

Appendix D: NASA Grease Smear Test Results: Field Notes

18"



LEFT OF CENTER

TEXTURE MEASUREMENTS

BASE: DUKE | RUNWAY: 18/36

DATE: 1/19/10 1/26/10 | PRIMARY END 18

PRE CLEAN POST

LOCATION FT FROM PRIMARY	LOCATION FT FROM CTR LINE	PAVEMENT TYPE	SURFACE RUBBER AT TEST	LENGTH OF 4" WIDE TEST STRIP INCHES	INCHES	AVERAGE TEXTURE MM	AVERAGE (in)
1025	7.5' L	AC	LIGHT	20.5		16	
1100	"	"	"	26.0		15	
1175	"	"	"	~~25.0~~ 23.0		14.5	
1250	"	"	"	34.5		15.5	
1325	"	"	"	19.0		16	
1400	"	"	"	33.0		22	
1475	"	"	"	17.5		16	
1550	"	"	"	30.0		16	
1625	"	"	"	22.5		18.25	
1700	"	"	"	25.5		18.5	
1775	"	"	"	30.0		15.25	
1850	"	"	"	18.0		15.00	

18

PRIMARY END

LEFT

RIGHT

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000

RIGHT OF CENTER

TEXTURE MEASUREMENTS

BASE:

RUNWAY:

DATE: 1/19/10 1/26/10

PRIMARY END:

LOCATION FT FROM PRIMARY	LOCATION FT FROM CTR LINE	PAVEMENT TYPE	SURFACE RUBBER AT TEST	PRE LENGTH OF 4" WIDE TEST STRIP INCHES	INCHES	POST AVERAGE TEXTURE ~~MM~~ INCHES	AVERAGE (in)
1025	75' R	AC	LIGHT	24.5		23.5	
1100	"	"	"	33.0		13.5	
1175	"	"	"	20.0		15.5	
1250	"	"	"	19.0		15.5	
1325	"	"	"	26.0		23	
1400	"	"	"	36.0		20.5	
1475	"	"	"	29.0		16.5	
1550	"	"	"	22.0		15.5	
1625	"	"	"	26.25		17.5	
1700	"	"	"	29.25		14.25	
1775	"	"	"	21.75		17.00	
1850	"	"	"	21.5		18.75	

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

°F	degrees Fahrenheit
AFCESA	Air Force Civil Engineering Support Agency
AFRL	Air Force Research Laboratory (Tyndall AFB)
ASTM	American Society for Testing and Materials
CFME	continuous friction measuring equipment
cm	centimeter(s)
cm^3	cubic centimeters
FOD	foreign object debris
ft	foot; feet
gal	gallon(s)
gal/min	gallons per minute
hrs	hours
in	inch(es)
kg	kilogram(s)
lb	pound(s)
µ	Mu
mm	millimeter
mph	miles per hour
MSDS	Material Safety Data Sheet
NASA	National Aeronautics and Space Administration
psi	pound per square inch
sec	second (time)
sq cm	square centimeter(s)
sq ft	square feet
sq ft/gal	square feet per gallon